The Implications of Lowering the Cost to Access Space on Airpower

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A thesis submitted to the faculty of the
School of Advanced Air and Space Studies
in partial satisfaction of graduation requirements for
School of Advanced Air and Space Studies Course 690

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Maxwell Air Force Base, Alabama

June 2017

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About the Author

Major Gabe Arrington is a 2003 graduate of the United States Air Force Academy, where he majored in Military History with a minor in Military Doctrine, Operations, and Strategy. A senior pilot with over 2,300 hours and 270 combat sorties in the C-17 and KC-135, he has also served in staff assignments at the 618 Air Operations Center and the LeMay Center Wargaming Institute. He holds master's degrees in national security studies from American Military University and military operational art from Air Command and Staff College, Air University, where he was a distinguished graduate.

Acknowledgements

I would like to thank the Air University Team at Maxwell Air Force Base, AL, for their support and mentorship during this research effort. In particular, I would like to thank Lt Gen Steven Kwast for his mentorship and the latitude that he has given research students in researching topics that impact Airmen across the United States Air Force.

This research would not have been possible without the support of the team at the School of Advanced Air and Space Studies. Dr. James Tucci and Dr. Derrick Frazier have helped shape my thoughts in this work and spent considerable time framing my views on strategy.

The LeMay Center Wargaming Institute and Air Force Research Laboratory are responsible for many of the wargames, workshops, and products referenced. Thank you for your leadership in this field and willingness to reach across institutions with an eye towards the future.

I'd like to thank the fine people from the following commands and organizations that have contributed to this research: United States Air Forces Europe, Air Education and Training Command, Air Mobility Command, Air Force Space Command, Air Force Global Strike Command, the Air Warfare Center, the Defense Advanced Research Projects Agency, Los Alamos National Laboratory, and Sandia National Laboratory. In particular, I'd like to thank Maj Gen Timothy Zadalis for his mentorship and willingness to expose the USAFE Team to emerging technology.

This research would not have been possible without the partnership of civilian industry partners and policy experts. My true appreciation goes to the Center for New American Security, the Heritage Foundation, the Center for Strategic and Budgetary Analysis, and SpaceWorks Enterprises.

To all that have helped in this endeavor and to the patriots who keep the United States safe…Thank You!

Abstract

This paper examines the implications that lowering the cost to access space will have on Airpower. The research conducted used predominantly qualitative research techniques to include interviews, primary sources, secondary sources, wargames, panel discussions, and site visits. Research included a wide range of topics including airpower, domestic policy, foreign policy, socioeconomic factors, and technological factors applicable to lowering the cost to access space, airpower theory, and application. An examination of these factors has led to the conclusion that the United States government should pursue and invest in a 'Fast Space Strategy' in the future.

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"We must bear in mind that airpower itself can become obsolete…"[1]

Chapter 1

Introduction

As the cost to access space lowers, how will airpower theory and application change? This research has relied upon qualitative research techniques to answer this question. The research included interviews, primary sources, secondary sources, wargames, panel discussions, and site visits. The interviews were conducted with professionals whose knowledge is applicable to air superiority, domestic policy, foreign policy, socioeconomic factors, and technological factors applicable to lowering the cost to access space, airpower theory, and application. To understand the impact of lowering the cost to access space, this study analyzes historical and contemporary theory and strategy, linking them to the historical and contemporary background of space access efforts. The research then compares these historical efforts to current research and development efforts to lower the cost to access space, linking them to emerging technologies that will impact research and development as well as contemporary theory and strategy. The shift in theory, strategy, and technology is impacting current government policy regarding space access. With changes in government policy come changes in government acquisition strategies. Ultimately, these cumulative changes lead to changes in the manner in which the United States Air Force will achieve its core missions in the future.

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[1] Yenne, Bill. *Hap Arnold: The General Who Invented the U.S. Air Force*. Washington, D.C.: Regnery History, (2013) 282.

The United States Air Force's Air University, think tanks, and industry partners have conducted wargames to analyze different aspects lowering the cost to access space. For this research I observed these wargames, analyzed their after action reports, and interviewed their participants.

Additionally, to aid in the study, I interviewed subject matter experts from United States Air Forces Europe to determine the potential impact of lowering the cost to access space would have on current operations. I also studied and considered current as well as future operational planning factors.

The United States is increasingly concerned with its ability to project power and influence world events.[2] A rapid change in technologies that enable asymmetric operations and their integration into strategies used by adversaries of the United States complicates matters, leading to non-traditional challenges.[3] Slower growth in the world economy has led to shrinking and static defense budgets not only for the United States, but for allies and adversaries as well.[4] A decrease in strategic defense spending over the last decade has steered defense investments in many areas including, but not limited to, basing, emerging technologies, future platforms, and force structure.[5]

The United States Air Force has committed itself to achieving operational agility in the future, making it the foundation for all of its missions to rely upon.[6] Operational

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[2] George, Robert. Comments made at the National Air and Space Intelligence Center. Wright-Patterson AFB, OH, 22 Sept 15.
[3] Colby, Elbridge. *From Sanctuary To Battlefield: A Framework for a U.S. Defense and Deterrence Strategy for Space.* Center for a New American Security, Jan 16.
[4] O'Hanlon, Michael. Interview at Brookings Institute. Washington, D.C., 19 May 16.
[5] Welsh, Mark A. III. *Air Force Challenges and Priorities.* Washington: Office of the Chief of Staff of the Air Force, 2016.
[6] Welsh, Mark A. III. *Air Force Future Operating Concept.* Washington: Office of the Chief of Staff of the Air Force, (2015), 4.

agility is "the ability to rapidly generate—and shift among—multiple solutions for a given challenge."[7] As the cost to access space is lowered, the United States Air Force will have the opportunity to achieve greater operational agility.[8] Operational agility will be required in the future in order for the United States Air Force to be successful across its mission set.[9] This ability will enable the United States Air Force to achieve its core missions of Multi-Domain Command and Control; Adaptive Domain Control; Global Integrated Intelligence, Surveillance, and Reconnaissance; Rapid Global Mobility; and Global Precision Strike in 2035.[10] The ability to deliver global effects rapidly will have implications for both domestic and foreign policy. This operational agility across the United States Air Force's core missions will enable the United States military to more effectively address its most pressing strategic challenge, Anti-Access Area Denial environments.[11]

The United States Air Force is currently facing multiple Anti-Access Area Denial (A2AD) challenges around the world that must be addressed. These presently include the East and South China Seas, Eastern Europe, the Gulf of Oman, and the Persian Gulf. In order to address A2AD challenges, the Air Force has identified operational agility as the cornerstone of the Air Force Future Operating Concept. For the United States Air Force

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[7] Welsh, Mark A. III. *Air Force Future Operating Concept.* Washington: Office of the Chief of Staff of the Air Force, (2015), 2.

[8] Welsh, Mark A. III. *Air Force Future Operating Concept.* Washington: Office of the Chief of Staff of the Air Force, (2015), 4.

[9] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.

[10] Welsh, Mark A. III. *Air Force Future Operating Concept.* Washington: Office of the Chief of Staff of the Air Force, (2015), 4.

[11] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.

to defeat A2AD challenges, lowering the cost of space access is prudent, achievable, and necessary.[12]

Technological research to lower the cost to access space is currently being conducted by the Department of Defense and commercial industry. Commercial investment has led to an environment in which the Technology Readiness Levels (TRLs) of the technologies needed to lower the cost to access space is achievable.[13] TRLs are a rating system used throughout engineering and technology fields to rate the maturity level of an emerging technology or group of technologies. The TRLs for the technologies currently being researched are at a TRL 4 or above. This allows for government investment later in the development process, thus cutting overall acquisition and costs to the U.S. government.[14]

The political environment is also calling for a change in investment strategies as they relate to technology. Senator John McCain has highlighted the need to allow the military services to have more ownership over their acquisition processes. In granting this, the armed forces will be better able to enforce acquisition reform and advance accountability.[15] He also stressed the importance of the National Defense Authorization

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[12] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[13] Miller, Charles. Comments made at the Pentagon during A Rapid Global Effects Capability meeting. Washington D.C., 7 Dec 15.
[14] Miller, Charles. Comments made at the Pentagon during A Rapid Global Effects Capability meeting. Washington D.C., 7 Dec 15.
[15] James, Deborah Lee. *Presentation to the Senate Armed Services Committee, United States Senate, Military Space Launch.* Washington, D.C., 27 January 2016.

Act (2015) and the need to incentivize commercial investment in a speech to the U.S. Chamber of Commerce.[16]

The 2015 U.S. National Security Strategy outlines the strategic foundation of the United States. It states, "The world is connected by shared spaces—cyber, space, air, and oceans—that enable the free flow of people, goods, services, and ideas. They are the arteries of the global economy and civil society, and access is at risk due to increased competition and provocative behaviors. Therefore, we will continue to promote rules for responsible behavior while making sure we have the capabilities to assure access to these shared spaces."[17] The Strategy notes that global access is a fundamental requirement of these shared spaces and is important for the global economy, peace, and progress. However, the United States must choose which development priorities are most important to its national security, particularly in the pursuit of emerging technologies that will lower the cost to access space or enable United States Air Force core mission effects in and through space.[18]

To maintain a dominant and balanced air, space, and cyberspace forces in the 2030s the United States armed forces must invest in *operational agility* enabled by emerging technologies to achieve their core missions.[19] In choosing its development

[16] McCain, John. *Remarks On Defense Acquisition Reform at the U.S. Chamber of Commerce.* Washington, D.C., 2015.
[17] The White House. *The National Security Strategy of the United States of America.* Washington D.C.: (2015), 12.
[18] James, Deborah Lee. *Third Offset Strategy Coordination and Synchronization.* Washington, D.C., 14 January 2016.
[19] James, Deborah Lee. *Third Offset Strategy Coordination and Synchronization.* Washington, D.C., 14 January 2016.

priorities, the United States must identify what it considers to be its strategic risks throughout the world. The 2015 National Security Strategy lists these strategic risks as:

- "Catastrophic attack on the U.S. homeland or critical infrastructure
- Threats or attacks against U.S. citizens abroad and our allies
- Global economic crisis or widespread economic slowdown
- Proliferation and/or use of weapons of mass destruction
- Severe global infectious disease outbreaks
- Climate change
- Major energy market disruptions
- Significant security consequences associated with weak or failing states (including mass atrocities, regional spillover, and transnational organized crime)."[20]

These strategic risks are global, broad, and increasingly dynamic in nature. As an example of a service's response to the identified strategic risks, in 2015 the United States Air Force produced the Air Force Future Operating Concept.

The Air Force Future Operating Concept is representative of each service's changing views on the character of warfare. It outlines what the United States Air Force believes the required force structure, missions, and investment strategy should be to effectively address the strategic risks outlined in the 2015 National Security Strategy. Written with an eye on the 2035-2040 timeframe, "it identifies four emerging trends that are highly likely to characterize the future: increasing speed and proliferation of technological change, geopolitical instability, increasing scarcity of natural resources, and an increasingly important and vulnerable global commons."[21] As a result of these

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[20] The White House. *The National Security Strategy of the United States of America.* Washington D.C.: (2015), 2.

[21] Welsh, Mark A. III. *Air Force Future Operating Concept.* Washington: Office of the Chief of Staff of the Air Force, (2015), 5.

emerging trends, the United States Air Force identifies operational agility as the cornerstone of future mission success.[22]

Operational agility will be the United States Air Force's and each service's key to future warfare.[23] The Air Force Future Operating Concept says that operational agility provides "the ability to rapidly generate—and shift among—multiple solutions for a given challenge."[24] It also says that operational agility will rely upon "flexibility, speed, coordination, balance, and strength."[25] As a key to future warfare, operational agility will ensure that the armed forces have the ability to react to a wide range of situations and threats anywhere in the world. Operational agility will allow the armed forces of the United States to achieve their missions.

The core missions that each service identifies aid them in achieving the national security priorities of the United States. The top priority of the Department of Defense (DoD) is to protect the United States and its citizens from attack. This has been the foundational charge to the nation's armed forces since the founding of the nation. To meet this requirement, each service in the DoD outlines their respective core missions. The core missions of each service have evolved with the current operating environment and geopolitical context. For instance, the Air Force Future Operating Concept highlights the evolution of the Air Force core missions as:

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[22] Welsh, Mark A. III. *Air Force Future Operating Concept.* Washington: Office of the Chief of Staff of the Air Force, (2015), 5.
[23] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[24] Welsh, Mark A. III. *Air Force Future Operating Concept.* Washington: Office of the Chief of Staff of the Air Force, (2015), 7.
[25] Welsh, Mark A. III. *Air Force Future Operating Concept.* Washington: Office of the Chief of Staff of the Air Force, (2015), 7.

1947	Today	Future
Air Superiority	Air & Space Superiority	Adaptive Domain Control
Air Reconnaissance	Global Integrated ISR	Global Integrated ISR
Airlift Mobility	Rapid Global Mobility	Rapid Global Mobility
Strategic Air Force	Global Strike	Global Precision Strike
Coordination of Air Defense	Command and Control	Multi-domain Command and Control

Figure 1 – Evolution of the Air Force Core Missions

Source: Welsh, Mark A. III. *Air Force Future Operating Concept.* Washington: Office of the Chief of Staff of the Air Force, (2015), 7.

Airpower and spacepower theory, international treaties, commercial research and investment, and United States Government policy and investment strategies are changing the manner in which space is viewed as a domain. Airpower and spacepower theory lay the foundation in which the discussion begins, directly influencing the other areas of study related to the research. International treaties link history, patterns of behavior, and accepted norms to how the air and space domains are changing today. Commercial research and development drive institutional change, forcing governments and societies to rethink theory and treaties in relation to modern capabilities.[26] Government policy and investment strategies adjust to represent current and future capabilities, national interests, and potential threats. Emerging technologies are enabling this evolution in United States Air Force core missions and are transforming the way that the United States Air Force conducts its missions in support of the National Security Strategy.[27] A wide range of emerging technologies have made it feasible to lower the cost to access space

[26] O'Hanlon, Michael. Interview at Brookings Institute. Washington, D.C., 19 May 16.
[27] James, Deborah Lee. *Third Offset Strategy Coordination and Synchronization.* Washington, D.C., 14 January 2016.

significantly.[28] These changes will have vital airpower and spacepower implications on both theory and application.

[28] Miller, Charles. Comments made at the Pentagon during A Rapid Global Effects Capability meeting. Washington D.C., 7 Dec 15.

Chapter 2

Military, Airpower, and Spacepower Theory and Strategy

Military theory is the foundation for strategy, which in turn changes the manner in which a strategist conceives theory. To understand the relationship between military theory and strategy, it is appropriate to establish a working definition of both. In addition, it is beneficial to comprehend the requirements of theory, levels of strategy, and the nature of strategic warfare. These realizations aid in the attainment of a pure outlook on strategy. A pure outlook on strategy allows optimization and ultimately reconceives theory across a strategy bridge.[29] Military theory is the beginning of a journey in search of "a better state of peace—even if only from your own point of view."[30]

Theorists, strategists, and visionaries such as Giulio Douhet, Alfred Mahan, Bernard Brodie, and Dr. Everett Dolman have influenced military, airpower, and spacepower theory and strategy to bring it to where it is today. Understanding these connections is crucial to analyzing the impact that low cost access to space will have on research and development, government policy, and United States Air Force applications.

Defining military theory allows for a starting point in the journey. While there are many definitions, for the purposes of this journey Clausewitz's definition is most appropriate. Clausewitz concludes, "The primary purpose of any theory is to clarify concepts and ideas that have become, as it were, confused and entangled."[31] This

[29] Gray, Colin. The Strategy Bridge: Theory for Practice, Oxford: Oxford University Press, (2011), 22.
[30] Liddell Hart, B.H. *Strategy*. 2nd rev. ed. 1967. (Reprint: New York: Penguin, 1991), 338.
[31] Clausewitz, Carl. *On War.* 1832. trans. And ed. Michael Howard and Peter Paret. (Princeton: Princeton University Press, 1984), 132.

clarification provides a starting point for the field of study. His definition of theory is applicable across a broad range on areas, including military theory as it relates to violence, chance, and reason. This particular aspect of Clausewitz's work makes it stand the test of time. Clausewitz also provides a timeless definition of strategy contemporary strategist Colin Gray has been able to adapt for modern security studies.

Clausewitz defines strategy as "the use of an engagement for the purpose of war. Though strategy in itself is concerned only with engagements, the theory of strategy must also consider its chief means of execution, the fighting forces."[32] Building upon these thoughts, Colin Gray provides a definition more applicable to the modern military strategist and our journey. His second dictum states, "Military strategy is the direction and use made of force and the threat of force for the purposes of policy as decided by politics."[33] This definition makes a necessary connection between military strategy and politics. This enhancement is consistent with Clausewitz's definition as it connects other critical aspects of his thoughts on strategy. For instance, Clausewitz states, "The political object—the original motive for the war—will thus determine both the military objective to be reached and the amount of effort it requires."[34] Thus, policy allows theory's requirements and the application of military strategy to connect on a strategy bridge.[35]

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[32] Clausewitz, Carl. *On War.* 1832. trans. And ed. Michael Howard and Peter Paret. (Princeton: Princeton University Press, 1984), 177.
[33] Gray, Colin. *The Strategy Bridge: Theory for Practice*. (Oxford: Oxford University Press, 2011,) 29.
[34] Clausewitz, Carl. *On War.* 1832. trans. And ed. Michael Howard and Peter Paret. (Princeton: Princeton University Press, 1984), 81.
[35] Clausewitz, Carl. *On War.* 1832. trans. And ed. Michael Howard and Peter Paret. (Princeton: Princeton University Press, 1984), 22.

Dr. Harold Winton, a former professor of military history and theory at the School of Advanced Air and Space Studies, provides five requirements to scope the study of theory.

Harold Winton considers a theory's ability to define, categorize, explain, connect, and anticipate as essential components in the relationship between military theory and strategy. For instance, the continental theory of warfare defines how a soldier views war though the lens of campaigns.[36] In categorizing military theory, Winton views Clausewitz as "instructive…War had two temporal phases: planning and conduct and two levels: tactics and strategy."[37] Explanation is the most critical requirement in theory. This aspect connects all of the other requirements, allowing the true intent of the theory to resonate with strategists. Explanation is the step that allows theory to "cast a steady light on all phenomena so that we can more easily recognize and eliminate the weeds that always spring from ignorance; it should show how one thing is related to another, and keep the important and the unimportant separate."[38] It is essential to connect military theory to other features of the world that may influence the theory. Lastly, Winton requires a theory to anticipate the future and the friction that may arise in its application. Once military theory has met these requirements, the various levels of strategy are accessible.

Edward Luttwak has chosen five levels of strategy on which strategists should focus. The five levels of strategy are technical, tactical, operational, theater, and grand

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[36] Wylie, Joseph. *Military Strategy: A General Theory of Power Control*. (Annapolis: Naval Institute Press, 1989), 42.
[37] Winton, Harold R. An Imperfect Jewel: Military Theory and the Military Profession. (*Journal of Strategic Studies, 2011*): 855.
[38] Clausewitz, Carl. *On War.* 1832. trans. And ed. Michael Howard and Peter Paret. (Princeton: Princeton University Press, 1984), 578.

strategy. The technical level of strategy, however, is perhaps the most debatable level among contemporary strategists. In analyzing the technical level of strategy, it is important for the United States government, military, and civilian industries to cooperate. This blended model of technical strategy development ensures that scientific advances that impact other levels of strategy are adequately communicated across government and industry. The technical change can vastly impact all other levels of strategy in warfare. During World War II, the technical development of the atomic bomb changed the other levels of strategy in warfare permanently. As a result, grand strategy changed and a new class of military theory in the form of nuclear deterrence emerged. J.C. Slessor agrees, "From time to time a new invention astonishes the world, and is hailed by the prophets as the forerunner of a revolution in the military art."[39] The four other levels of strategy are more common in modern warfare terminology.

The remaining echelons of strategy are of equal importance to the first. The tactical level is that of engagement. The operational level is a series of engagements. Luttwak uses the modern situation between South and North Korea to highlight a theater level strategy. The theater level of strategy in Korea has a character of elastic defense.[40] Grand strategy is national strategy in which the military strategy, or multiple military strategies, compose but one part. Luttwak's five levels of strategy are both horizontal and vertical.

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[39] Slessor, J.C. *Air Power and Armies*. 1936. (Reprint, Tuscaloosa: University of Alabama Press, 2009), 200.
[40] Luttwak, Edward. *The Logic of Strategy in War and Peace*, Revised and expanded edition. (Cambridge, MA: Belknap, 2002), 138.

The vertical and horizontal nature of strategy allow for dynamic application and growth. The vertical nature of strategy is obvious to most. At one end is the technical level, characterized by engineering, research, and development. The other end is grand strategy, in which many strategies converge. The vertical strategy aspect allows for a strategy at one level to influence the strategies at other levels. The horizontal dimension is one "in which the dynamic logic of action and reaction unfolds within each level."[41] Thus, a strategy level can influence all the other levels through the vertical and horizontal framework. Growth through the strategy levels allows for effective strategy development.

Strategy development begins with military theory. Modern theorist Everett Dolman emphasizes, "We need theory to cope with a world that is so unfathomably intricate."[42] Insight such as this leads to force development and the associated force employment for the military. For instance, the United States is creating and employing a force that focuses on information dominance to counter asymmetric threats. Airpower is the primary means in which the United States is pursuing this goal. Information dominance in this instance has various targets. They include targets for kinetic strike, sensitive information, or the population of a nation. The mechanism in which to affect these targets include remotely piloted aircraft, cyberattacks, or satellite imagery. The chosen means, target, and mechanism influence the desired outcome. These relationships in strategy development create a situation in which the overall military strategy is

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[41] Luttwak, Edward. *The Logic of Strategy in War and Peace*, Revised and expanded edition. (Cambridge, MA: Belknap, 2002), 90.
[42] Dolman, Everett. *Pure Strategy: Power and Principle in the Space and Information Age*. (London: Routledge, 2005), 12.

immediately and continuously impacted. The process of strategy development provides the setting for the next phase of the journey, that of attaining pure strategy.

Clausewitz says, “In strategy there is no such thing as victory.”[43] This is the essence of military strategy. It is continuous and has no end. There will be continual conflict in the world because human nature focuses on self-interest, fear, and honor. Undoubtedly, these focal points lead to conflict. The Allied victory in World War II provided a setting for the United States and Soviet Union to fear each other’s influence on the world. A bipolar power dynamic set the world stage for smaller conflicts around the world for the next forty years between competing ideologies. “Like politics, strategy is a state of being, not a series of events.”[44] The historical roots of strategy allowed the development of airpower theory.

Giulio Douhet is considered the ‘Grandfather’ of aviation theory. His observations on early aviation have implications for airpower and spacepower thought today. For instance, in 1921 he observed:

> The technico-practical problem faced by aviation is to make aerial navigation safer, more dependable, more economical, and in general better suited to the needs of society. Study of the problem is therefore directed toward realizing these four aims: 1. To increase the safety of flying and of take-off and landing facilities. 2. To exclude materials which warp and deteriorate in use today in the construction of airplanes. 3. To increase the carrying capacity and radius of action of airplanes. 4. To increase the speed and give better performance on less fuel. Improvement along these lines will give the airplane much greater utility in peacetime and in wartime as well.[45]

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[43] Clausewitz, Carl. *On War.* 1832. trans. And ed. Michael Howard and Peter Paret. (Princeton: Princeton University Press, 1984), 363.
[44] Dolman, Everett. *Pure Strategy: Power and Principle in the Space and Information Age*. (London: Routledge, 2005), 15.
[45] Douhet, Giulio. *The Command of the Air. 1921, Reprint*. (Tuscaloosa: University of Alabama Press, 2009), 62.

Profoundly, these four aims hold true in the aviation industry almost a century after Douhet first observed them. Modern commercial aviation companies are in a continuous pursuit of safer, faster, and cheaper applications to change the way that airplanes operate. The same can be said about current commercial space companies pursuing various interests in space. Reusable space launch assets are being heavily invested in with an eye towards lowering the cost for overall recurring launch, and therefore the cost to access space. Douhet also advocated for,

> The development of the aviation industry by giving it protection, publicizing it, and giving it funds for research and experiment…" as well as "the development of aerial navigation and a national aviation industry by provisions for transforming them quickly into instruments of war; whereby a large part of the money assigned by the state for national defense could profitably be employed to further the development of peacetime civil aviation.[46]

Many airpower and spacepower advocates argue that Douhet's early proclamations regarding the relationship between commercial aviation development and government investment, regulation, and partnership hold true today. Both military and civilian strategists have identified the link between early aviation advancements and current space launch advancements. The idea of government protection and investment in the emerging technologies that will decrease the cost of space access has merit and is supported with the history of early aviation development. Likewise, the military application of aviation once it became more developed is linked to the potential military applications of rapid access to space as technology pushes advances and ease of access.

The link between military and civilian aviation, as well as potential benefits of the

[46] Douhet, Giulio. *The Command of the Air. 1921, Reprint*. (Tuscaloosa: University of Alabama Press, 2009), 81.

relationship, are evident to Douhet. He says, “Military aviation can do much for civil aviation while still acting in its own interest and avoiding interference, provided that the diverse interests of the two branches are clearly defined, and that we act with magnanimity, without misconceptions, cutting away the traditions which have already grown up about aviation in spite of its youth.”[47] Thus, Douhet is the first advocate for a partnership between commercial and government development in the emerging air domain. Referencing the history of World War I, Douhet contends, “Aviation entered the war more from tolerance than from conviction, more in deference to public opinion—which was more clear-sighted than the military-technical authorities—than in the belief that it might be valuable.”[48] Historically, as Douhet proves with the example from World War I, governments can be reluctant to adopt the earliest technological developments in new domains for military uses. Douhet also advocates for an offensive strategy when implementing the airplane for military use. He stresses, “To get behind the enemy aerial defense and at the same time avoid aerial combat, superior speed and more skillful flying than the enemy can oppose to it are necessary.”[49] Airpower strategists have used this as the basis for the belief in the strength in the offensive use of airpower, and current spacepower strategists are beginning to adopt this attitude as well. Like Douhet, spacepower advocates are facing similar challenges to government applications of

[47] Douhet, Giulio. *The Command of the Air. 1921, Reprint*. (Tuscaloosa: University of Alabama Press, 2009), 85.
[48] Douhet, Giulio. *The Command of the Air. 1921, Reprint*. (Tuscaloosa: University of Alabama Press, 2009), 101.
[49] Douhet, Giulio. *The Command of the Air. 1921, Reprint*. (Tuscaloosa: University of Alabama Press, 2009), 120.

technological developments in emerging space technologies. Another early advocate of airpower was General William “Billy” Mitchell.

If Douhet is the ‘Grandfather’ of aviation, Mitchell is the ‘Father’ of military aviation in the United States. After his experiences during World War I, “Mitchell returned to the United States fully determined to bring about a revolution in American military policy by persuasion alone.”[50] He used his experiences from the war, combined them with his knowledge of emerging technologies that were changing aviation and warfare, and used them to look ahead to the next war.[51] With an eye towards the future, Mitchell was a strong advocate for expanding the role of military aviation. However, “America’s return to what its next President, Warren G. Harding, described as “normalcy,” almost wrecked the nation’s armed forces.”[52] This sentiment was widespread and became a cornerstone of domestic politics in the United States as the military was downsized in the aftermath of World War I. As each military service fought for budgetary consideration, an expanding military aviation role was difficult to justify. “Despite aviation’s poor position in the United States, informed congressmen knew what had been accomplished overseas and recognized that there must be room in the national defense structure for the air weapon.”[53] Mitchell chose to echo many of Douhet’s arguments to push the military use of aviation in the United States.

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[50] Hurley, Alfred. *Billy Mitchell: Crusader for Airpower.* (Bloomington: Indiana University Press, 1975), 39.
[51] Hurley, Alfred. *Billy Mitchell: Crusader for Airpower.* (Bloomington: Indiana University Press, 1975), 39.
[52] Hurley, Alfred. *Billy Mitchell: Crusader for Airpower.* (Bloomington: Indiana University Press, 1975), 41.
[53] Hurley, Alfred. *Billy Mitchell: Crusader for Airpower.* (Bloomington: Indiana University Press, 1975), 42.

Like Douhet, Mitchell "emphasized offensive action as the best defense."[54] Mitchell also argued that the various forms of emerging aviation were linked. "A new framework, Mitchell asserted, must include a Department of Aeronautics supervising military, civil, and commercial aviation."[55] Today, this is the modern Federal Aviation Administration (FAA). The FAA has grown to include being a governing body on some aspects of space launch. Mitchell also thought "the creation of a new service, he thought, must lead to a "Ministry of Defense" to coordinate the activities of the three services and to assign to each its proper role in war."[56] The United States shifted from a 'War Department' to a modern Department of Defense, aligning with Mitchell's vision. Similar to Mitchell's demand for an independent Air Force, the argument has been made that eventually space will become such an expansive domain that a new military service will need to be created.

Bernard Brodie shifted strategic thought and theory in the 1950s in his revelations regarding the use of nuclear capable intercontinental ballistic missiles. He said, "We have a situation for the first time in history where the opening event by which a great nation enters a war—an event which must reflect the preparations it has made or failed to make beforehand—can decide irretrievably whether or not it will continue to exist."[57] Brodie's considered nuclear warfare an unthinkable act, and his thoughts continue to

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[54] Hurley, Alfred. *Billy Mitchell: Crusader for Airpower.* (Bloomington: Indiana University Press, 1975), 43.
[55] Hurley, Alfred. *Billy Mitchell: Crusader for Airpower.* (Bloomington: Indiana University Press, 1975), 45.
[56] Hurley, Alfred. *Billy Mitchell: Crusader for Airpower.* (Bloomington: Indiana University Press, 1975), 47.
[57] Brodie, Bernard. *Strategy in the Missile Age*. (Princeton, N.J: Princeton University Press, 1959. Print), 7.

drive nuclear war and airpower theory and strategy today. Brodie became a strong advocate of how technological development changes warfare. For instance, he proposed, "The intensely conservative among the military are always proved wrong, because changes in armaments over the past century have been altogether too rapid and drastic to offer any cover to those who will not adjust."[58] Thus, Brodie was an advocate of advancing ideas on the leading edge of military thought in order to maintain a competitive advantage against an enemy. He also became to believe in the power of the offensive over the defensive nature of warfare. Brodie notes, "The old adage that every new offensive development inevitably provokes the development of a suitable defense is hard to justify historically, and it is certainly excessively optimistic for the nuclear era."[59] Brodie's thoughts in the nuclear and missile age have implications across technological developments. One could argue that to maintain a competitive advantage, aggressive pursuit of offensive technological progress should be made. Space theory and strategy have deep roots in naval theory. A. T. Mahan and Julian Corbett's work about the use and control of the sea inform the modern strategist's use of air and space as instruments of national power.

Mahan stresses the importance of sea power in national historical supremacy. He uses Jominian principles to conclude that military and commercial control of the sea is crucially linked, and that commerce via sea lines of communication are critical in determining the outcome of wars between nations. Mahan stresses "the first and most

[58] Brodie, Bernard. *Strategy in the Missile Age*. (Princeton, N.J: Princeton University Press, 1959. Print), 172.
[59] Brodie, Bernard. *Strategy in the Missile Age*. (Princeton, N.J: Princeton University Press, 1959. Print), 221.

obvious light in which the sea presents itself from the political and social point of view is that of a great highway; or better, perhaps, of a wide common, over which men may pass in all directions, but on which some well-worn paths show that controlling reasons have led them to choose certain lines of travel rather than others."[60] He uses the historical example of the British control of seaborne commerce through its military and commercial strength on the sea to demonstrate its rise to power. Due to Great Britain's strength on the seas, they were able to become the leading power economically, politically, socially, and militarily.

Mahan also illustrates the importance of British control of sea power and controlling commerce during the American Revolution. He notes, "As to the sea warfare in general, it is needless to enlarge upon the fact that the colonists could make no head against the fleets of Great Britain, and were consequently forced to abandon the sea to them, resorting only to a cruising warfare, mainly by privateers, for which their seamanship and enterprise well fitted them, and by which they did much injury to English commerce."[61] The colonies only truly grasped the importance of sea power for the U.S. was apparent when the French came to their aid, forcing the British to further expand their naval forces instead of concentrating solely on the 13 colonies. Later, Washington proclaimed that sea power would be foundational to the future security of the United States. Like Mahan, Julian Corbett stresses the importance of the sea. Corbett, however, links naval strategy to land warfare as a part of national strategy.

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[60] Mahan, Alfred Thayer. The Influence of Sea Power upon History, 1660-1783. 5th ed. 1894. Reprint, Mineola, NY: Dover, (1987) 25.
[61] Mahan, Alfred Thayer. The Influence of Sea Power upon History, 1660-1783. 5th ed. 1894. Reprint, Mineola, NY: Dover, (1987), 344.

Corbett believes, "The object of naval warfare must always be directly or indirectly either to secure the command of the sea or to prevent the enemy from securing it."[62] This is an important aspect for contemporary strategists to remember. Preventing an enemy from securing command can be just as effective as securing command yourself. Corbett expands on this thought, saying, "If the object of naval warfare is to control communications, then the fundamental requirement is the means of exercising that control."[63] He then links sea lines of communication to lines of operation, using a Clausewitzian view on warfare to stress the importance of "the fleet in being." Ultimately, Corbett believes in the value of defensive warfare, similar to Clausewitz. This allows for his belief in the benefit of using concentration and flexibility in warfare to dispute command of the sea or exercise control of communications. These historical lessons regarding the importance of Mahan's sea lines of communication in relation to commerce and the Corbett's concept of a "fleet in being" are evident in how the United States approaches air and space operations and the mindset in which its future strategy is constructed.

Today's air, space, and cyberspace lines of communication are as critical to the information age as sea lines of communication were to the budding industrial age. Combining Mahan and Corbett's wisdom into the Future Operating Concept will allow the United States to rapidly deter and defeat aggression around the world, to include anti-access area denial threats from adversaries like China.

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[62] Corbett, Julian. Some Principles of Maritime Strategy. 1907. Introduction and Notes by Eric J. Grove. Annapolis: Naval Institute Press, (1988) 63.
[63] Corbett, Julian. Some Principles of Maritime Strategy. 1907. Introduction and Notes by Eric J. Grove. Annapolis: Naval Institute Press, (1988) 79.

The United States Air Force is using the principles that Mahan and Corbett identify to counter China in air, space, and cyberspace. For instance, the Air Force routinely flies missions to ensure access to air lines of communication in international airspace throughout the East and South China Sea. Also, commercial air carriers from various countries also fly these routes, maintaining access to established trade routes via the air. The combination of military and commercial aviation is a lesson from Mahan. Many strategists are concerned over China's creation of islands in the South China Sea, fearing that China will cut off critical trade routes. Maintaining a military presence and flying in international airspace is the United States Air Force's modern "fleet in being." By having a presence as an "Air Force in being," the United States is presently a credible deterrent to further aggression. There are also examples from space as well.

The United States Air Force and government at large has partnered with civilian industry to ensure access to space. This partnership is representative of the importance that Mahan placed on control of the sea through a joint military and commercial presence. This strategy ensures access to space while decreasing and ultimately eliminating dependence on foreign launch assets.

Similarly, the United States Air Force is partnering with civilian industry to secure command of space as Corbett advises. To do so, commercial industry has developed CubeSats. Their goal is to facilitate "frequent and affordable access to space with launch opportunities available on most launch vehicles."[64] The critical aspect of CubeSats is that they are significantly smaller and lighter than historically built

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[64] CubeSat. http://www.cubesat.org

satellites.[65] By being smaller and lighter, CubeSats are easier to launch into orbit. This is a counter to China's displayed Anti-Satellite weapons. The United States can now easily and cheaply launch small satellites to replenish capability in comparison to historical timelines and cost structures. Thus, the United States has a satellite "fleet in being" capability and operational agility in space.

The United States uses A. T. Mahan and Julian Corbett's work about the use and control of the sea to create portions of the national security strategy. The United States Air Force has chosen to take the lessons from theses theorists to inform the modern strategist's use of air and space as instruments of national power. Their guidance is foundational in the development of the United State Air Force's Future Operating Concept. Mahan and Corbett have decidedly influenced how the United States approaches instruments of national power, to include air, space, and cyberspace strategies against potential adversaries like China. Two twenty-first century airpower strategists that would agree with this these naval theorists are John Warden and John Boyd.

In his article entitled, "John Boyd and John Warden: Airpower's Quest for Strategic Paralysis," in Phil Meilinger's *The Paths of Heaven,* David Fadok contends that "the paralysis theories of Boyd and Warden represent a fundamental shift in the evolution of strategic airpower thought from an emphasis on economic warfare to an emphasis on control warfare."[66] Together, these theorists pushed airpower theory and strategy from its classical roots, taking lessons from the missile era, and applied emerging technologies to

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[65] Smith, Michael. Comments made at the Center for Strategic and Budgetary Assessments Space Workshop. Washington D.C., 9 and 10 Nov 15.

[66] Fadok, David. "John Boyd and John Warden: Airpower's Quest for Strategic Paralysis," in Phil Meilinger, ed. *The Paths of Heaven*. (Maxwell AFB: Air University Press, 1997), 358.

create a modern, dominant form of airpower late in the twenty-first century. While "Warden's thoughts are predominantly Jominian in their character, content, and intent, while Boyd's are predominantly Clausewitzian."[67]

Warden's thinking has become known as "Warden's Five Rings." His five rings are levels of attack that focus on leadership in the center, moving out with system essentials, infrastructure, population, and the enemy's fielded forces. He "advocates paralysis through control warfare based on command targeting."[68] Warden also realizes that his five rings are connected in ways that can't be seen or measured. In effect, the enemy is a living organism that is in constant movement and development. "Warden also recognizes the importance of information management to the effective operation of the enemy as a system, speculating that the five strategic rings are connected by an "information bolt" that holds all the rings in place."[69]

John Boyd is known for his concept of observe, orient, decide, act, or "OODA Loop."[70] He is "one contemporary theorist who focuses on paralysis through control warfare."[71] During Operation Desert Storm, the United States was successful in its application of the OODA Loop strategy against Iraq. Its use, however, was mostly at the

[67] Fadok, David. "John Boyd and John Warden: Airpower's Quest for Strategic Paralysis," in Phil Meilinger, ed. *The Paths of Heaven*. (Maxwell AFB: Air University Press, 1997), 381.
[68]Fadok, David. "John Boyd and John Warden: Airpower's Quest for Strategic Paralysis," in Phil Meilinger, ed. *The Paths of Heaven*. (Maxwell AFB: Air University Press, 1997), 384.
[69] Fadok, David. "John Boyd and John Warden: Airpower's Quest for Strategic Paralysis," in Phil Meilinger, ed. *The Paths of Heaven*. (Maxwell AFB: Air University Press, 1997), 385.
[70] Freedman, Lawrence. *Strategy: A History*. (Oxford University Press, 2013), 196.
[71] Fadok, David. "John Boyd and John Warden: Airpower's Quest for Strategic Paralysis," in Phil Meilinger, ed. *The Paths of Heaven*. (Maxwell AFB: Air University Press, 1997), 384.

tactical and operational levels of strategy. Boyd and Warden differ slightly in their thoughts on paralysis.

"Boyd's thoughts are process oriented and aim at psychological paralysis."[72] In contrast, "Warden's theory of strategic attack is form oriented and aims at physical paralysis."[73] These two theorists' efforts have combined the strategic bombing theories of World War II with emerging technologies to create an updated twenty-first century airpower theory and strategy. "Together, Boyd and Warden have transformed paralysis theory as it pertains to strategic conventional airpower."[74]

Like classical airpower theorists, Boyd and Warden identified technological development as a key to airpower theory and strategy. In particular, Warden advocates for high-tech solutions. Basic to his appeal for parallel attack is the assumption that the coming of precision-guided munitions (PGM) and stealth make possible the fulfillment of many of the older theorists' claims that the destruction of a given target required a far smaller strike force than heretofore, and with stealth no supporting aircraft is needed."[75] Modern-day theorist Dr. Everett Dolman pushes airpower and spacepower theory and strategy even further.

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[72] Fadok, David. "John Boyd and John Warden: Airpower's Quest for Strategic Paralysis," in Phil Meilinger, ed. *The Paths of Heaven*. (Maxwell AFB: Air University Press, 1997), 388.
[73] Fadok, David. "John Boyd and John Warden: Airpower's Quest for Strategic Paralysis," in Phil Meilinger, ed. *The Paths of Heaven*. (Maxwell AFB: Air University Press, 1997), 388.
[74] Fadok, David. "John Boyd and John Warden: Airpower's Quest for Strategic Paralysis," in Phil Meilinger, ed. *The Paths of Heaven*. (Maxwell AFB: Air University Press, 1997), 385.
[75] Mets, David. *The Air Campaign: John Warden and the Classical Airpower Theorists*. (Maxwell AFB: Air University Press, 1999), 63.

Dolman's pure strategy concept allows the military "genius" to learn lessons from the grand strategy level. Humanity's journey into space is a prime example. Dolman relates, "It remains a universal axiom that the side capable of outmaneuvering the other will have an advantage, all other variables held constant."[76] While not feasible to hold all other variables constant, the importance in maneuver in warfare holds true. This is a belief that most airpower, and military strategists, would prescribe to. Dolman expands this statement to speak about the importance of time. "Time is the most critical limitation on the power the tactician can yield, and the most malleable enabler that the strategist can manipulate."[77] Dolman, in his journey in the exploration of strategy, is opening up a new way of thinking regarding time. He begins to explore ways in which the strategist can manipulate time in warfare to have an impact at the tactical, operational, and strategic levels. While classical airpower theorists have focused on tactical and operational effects on the battlefield, Dolman warns that a strategist can only have a meaningful grasp of so much detail.[78] As such, "scope refers to the breadth of vision the strategist can maintain, and for this it is critical not to telescope or scale down into the details of the specific."[79] Dolman's thoughts on the role of time in warfare bring him to a domain in which airpower theory has yet to fully explore, space.

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[76] Dolman, Everett. *Pure Strategy: Power and Principle in the Space and Information Age*. (London: Routledge, 2005), 151.
[77] Dolman, Everett. *Pure Strategy: Power and Principle in the Space and Information Age*. (London: Routledge, 2005), 151.
[78] Dolman, Everett. Interview conducted at Air University. Maxwell AFB, AL, 2 Dec 15.
[79] Dolman, Everett. *Pure Strategy: Power and Principle in the Space and Information Age*. (London: Routledge, 2005), 159.

Dolman applies his thoughts on strategy to space in his book, *Astropolitik: Classic Geopolitics in the Space Age.* Throughout his work, Dolman proposes five primary thoughts:

> First, many classical geopolitical theories of national military development are fully compatible with, and will prove readily adaptable to, the realm of outer space.
>
> Second, the most applicable of these theories will be military power assessments of geographical position in light of new technologies. Such assessments have been made for sea, rail, and air power, and can be viewed with analytic perspicacity as segments of an evolutionary process. Space power is their logical and apparent heir.
>
> Third, the special terrain of solar space dictates specific tactics and strategies for efficient exploitation of space resources. These strategies impact on political development, highlighting the geo/astrodeterminist political relationship.
>
> Fourth, the concept of space as a power base in classical, especially German, geopolitical thought will require some modification, but will easily conform to the exploitation and use of outer space as an ultimate national power base.
>
> Finally, a thorough understanding of the astromechanical and physical demarcations or outer space can prove useful to political planners, and will prove absolutely critical to military strategists.[80]

Dolman takes these primary considerations to conclude that those who control low-Earth orbit will ultimately control the movement and actions of Earth as well.[81] He bases this thoughts largely on historical sea theorists like Mahan. He contends, "Space, like the sea, can potentially be traversed in any direction, but because of gravity wells and the forbidding cost of getting fuel to orbit, over time spacefaring nations will develop

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[80] Dolman, Everett C. *Astropolitik: Classic Geopolitics in the Space Age*. (London: Frank Cass, 2002), 7.
[81] Dolman, Everett C. *Astropolitik: Classic Geopolitics in the Space Age*. (London: Frank Cass, 2002), 8.

specific pathways of heaviest traffic."[82] These pathways of heaviest traffic will create strategic chokepoints similar to chokepoints for commerce on Earth, such as the Panama Canal.[83] There is significant correlation between strategic chokepoints, commerce, and political capitol. Dolman defines this relationship as Astropolitics.

Astropolitics is "the study of the relationship between outer space terrain and technology and the development of political and military policy and strategy."[84] While using primarily a naval theorist mindset to highlight the importance of Astropolitics, there are also elements of airpower theory from Douhet and Mitchell, such as the importance of vital centers.[85] Dolman stresses the importance of Hohmann transfer orbits as the future space lines of communication and commerce based on their strategic placement in orbit and necessity to future on-orbit refueling and basing operations.[86] Due to the significance of the Hohmann transfer orbits and their relationship to future commerce and exploration, Dolman argues for the United States to advance into space.

"The ultimate goal of astropolitics and Astropolitik is not the militarization of space. Rather, the militarization of space is a means to an end, part of a longer-term strategy."[87] Dolman urges the advancement of the United States military into space in an

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[82] Dolman, Everett C. *Astropolitik: Classic Geopolitics in the Space Age*. (London: Frank Cass, 2002), 39.
[83] Dolman, Everett C. *Astropolitik: Classic Geopolitics in the Space Age*. (London: Frank Cass, 2002), 39.
[84] Dolman, Everett C. *Astropolitik: Classic Geopolitics in the Space Age*. (London: Frank Cass, 2002), 39.
[85] Dolman, Everett C. *Astropolitik: Classic Geopolitics in the Space Age*. (London: Frank Cass, 2002), 50.
[86] Dolman, Everett C. *Astropolitik: Classic Geopolitics in the Space Age*. (London: Frank Cass, 2002), 73.
[87] Dolman, Everett C. *Astropolitik: Classic Geopolitics in the Space Age*. (London: Frank Cass, 2002), 183.

effort to control the future space commons, or the Hohmann transfer orbits, in order to ensure the positive expansion of humankind into space. "It is a neoclassical, market-driven approach intended to maximize efficiency and wealth."[88] To do so, Dolman recommends withdrawing from the 1967 Outer Space Treaty, seeing it as a product of a bipolar world and out of touch with emerging technologies that will drive the cost to access space down.

In his comments at the Heritage Foundation in Washington, D.C., Dolman applies his thoughts on pure strategy to the current state of the United States military.[89] He views the current actions of civilian industry leaders in the space sector, such as SpaceX and Planetary Resources, as creating a new dimension of space warfare.[90] As the price to access space decreases, human nature will drive humans into further space exploration due to self-interest.[91] Mr. Peter Marquez, Vice-President of Global Engagements at Planetary Resources, agrees with Dolman.[92]

Mr. Marquez highlighted how Planetary Resources is acquiring minerals from space during his comments at the Secure World Foundation in Washington, D.C.[93] President Obama's recent signing of the U.S. Commercial Space Launch

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[88] Dolman, Everett C. *Astropolitik: Classic Geopolitics in the Space Age*. (London: Frank Cass, 2002), 183.
[89] Heritage Foundation Panel. Comments by Dr. Everett Dolman, Professor, Air University, United States Air Force. Washington D.C., 11 May 2016.
[90] Dolman, Everett. Interview conducted at Air University. Maxwell AFB, AL, 2 Dec 15.
[91] Dolman, Everett. Interview conducted at Air University. Maxwell AFB, AL, 2 Dec 15.
[92] Secure World Foundation Panel. Comments by Mr. Peter Marquez, Vice-President, Global Engagement at Planetary Resources. Washington D.C., 5 May 2016.
[93] Secure World Foundation Panel. Comments by Mr. Peter Marquez, Vice-President, Global Engagement at Planetary Resources. Washington D.C., 5 May 2016.

Competitiveness Act (H.R. 2262) supports this viewpoint.[94] This law outlines how the United States government views commercial expansion in space in relation to capitalism as well as the responsibilities of some government agencies.[95] Unfortunately, the role of the Department of Defense is noticeably lacking.[96] The only reference states, “It is the sense of Congress that the Department of Defense (DOD) plays a vital and unique role in the protection of national security assets in space.”[97] The pure strategist, or military genius, links developing economic theory[98] to the future of military theory and strategy.[99]

Dolman believes that space will become a contested environment as industry and states expand into that domain, consequently changing military theory and strategy.[100] As history has proven, states will use their militaries to protect their populace and interests in a contested environment. Thus, technical developments in economic strategies have produced a modern need for a new military strategy in the changing domain of space.[101] The need for a new military strategy at the technical level will drive

[94] 114th Congress of the United States of America. *U.S. Commercial Space Launch Competitiveness Act.* Washington D.C.: Government Printing Office, (2015) HR 2262.
[95] Colby, Elbridge. *The Implications of the Commercialization of Space and ULCATS for a U.S. Limited War Defense and Deterrence Strategy for Space.* Washington, D.C.: Center for a New American Security, Nov 16.
[96] Secure World Foundation Panel. Comments by Mr. Peter Marquez, Vice-President, Global Engagement at Planetary Resources. Washington D.C., 5 May 2016.
[97] 114th Congress of the United States of America. *U.S. Commercial Space Launch Competitiveness Act.* Washington D.C.: Government Printing Office, (2015) HR 2262.
[98] Colby, Elbridge. *The Implications of the Commercialization of Space and ULCATS for a U.S. Limited War Defense and Deterrence Strategy for Space.* Washington, D.C.: Center for a New American Security, Nov 16.
[99] Miller, Charles. Comments made at the Pentagon during A Rapid Global Effects Capability meeting. Washington D.C., 7 Dec 15.
[100] Dolman, Everett. Interview conducted at Air University. Maxwell AFB, AL, 2 Dec 15.
[101] Miller, Charles. Comments made at the Pentagon during A Rapid Global Effects Capability meeting. Washington D.C., 7 Dec 15.

change in the vertical dimension of strategy at every level, including grand strategy.[102] Changes at every level of strategy will force the development of new military theory as well as policy.[103] This pure strategist, or Dolmanian, way of thinking is rooted in history and relationships.

The classic airpower theorist Giulio Douhet reminds us to "keep in mind, not what aviation is today, but what it could be today."[104] The military genius looks through history, at contemporary issues, and into the future to apply and change theory and strategy across the strategy bridge. With an eye on theory, genius further links different strategies from different fields and anticipates how each will change. This concept "rests inextricably on the notion of symmetry: of power or force for military strategy, public support for political strategy, wealth for economic strategy, and perhaps morality for socio-cultural strategy."[105] These relationships are why genius prefers to have access to as much information as possible. Ultimately, it is important to remember, "Radical changes in established ways of thinking often come from the margins of theory."[106] As the cost to access space decreases, military, airpower, and spacepower theory and strategy will be forced to change with it.[107]

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[102] O'Hanlon, Michael. Interview at Brookings Institute. Washington, D.C., 19 May 16.
[103] Dolman, Everett. Interview conducted at Air University. Maxwell AFB, AL, 2 Dec 15.
[104] Douhet, Giulio. *The Command of the Air. 1921, Reprint*. (Tuscaloosa: University of Alabama Press, 2009), 126.
[105] Dolman, Everett. *Pure Strategy: Power and Principle in the Space and Information Age*. (London: Routledge, 2005), 156.
[106] Dolman, Everett. *Pure Strategy: Power and Principle in the Space and Information Age*. (London: Routledge, 2005), 96.
[107] Dolman, Everett. Interview conducted at Air University. Maxwell AFB, AL, 2 Dec 15.

Chapter 3

Space Access Background

The history of laws governing access to space is relatively young and underdeveloped in comparison to laws governing the domains of land, sea, and air. Domestic policies and treaty obligations have shaped how the United States has pursued developing technologies since the end of World War II. New industries based on German V2 rocket developments and other advancements in radar have shaped the industries that impact lowering the cost to access space. The professionals involved in these early projects applied lessons from early rockets to create space vehicles such as the X-20, X-15, and space shuttle programs. The 1967 Outer Space Treaty, Strategic Arms Limitation Talks (SALT-II), and Strategic Arms Reduction Treaty are three pieces of legislation that have implications for advancing airpower and spacepower theory and strategy[1] into the future. Also, there are international airspace questions that arise regarding some emerging technologies that are changing how humanity views space. Early rocket development, early space vehicle programs, and international treaties all impact humanity's view on the space domain. This view is a driving factor in lowering the cost to access space.

After World War II, engineers and scientists around the world were faced with the increasing complexity of technological development projects. In order to address these challenges, a systems approach to engineering and problem solving was widely instituted

[1] Heritage Foundation. Interview with Mr. Dean Cheng. Washington D.C., 2 March 2016.; Heritage Foundation. Interview with Mr. John Venable. Washington D.C., 2 March 2016.; Heritage Foundation. Interview with Ms. Michaela Dodge. Washington D.C., 2 March 2016.

across industry and academia. The United States government, as well, adopted the systems approach to its development projects on the insistence of General Hap Arnold.[2] In creating the new United States Air Force, Arnold was also interested in establishing a research center that could help with strategic issues.[3] Today, RAND is a bedrock of strategic thought for the United States Air Force. Arnold had created the relationship between the government, industry, and academia needed to manage the technological change that was on the horizon.[4] As such, defense projects were able to attract the best scientists and engineers beginning in about 1950. The professionals that became involved in defense projects not only believed that they were helping their country in efforts vital to its national security, but also had the professional latitude they desired to advance their particular fields of science.[5] One of the first defense projects to use a systems approach to development was the Semi-Automatic Ground Environment (SAGE).

SAGE was a historic Cold War development project. Its design provided the United States with an early warning capability against a Soviet Union nuclear bomber attack. Unprecedented for the time, SAGE utilized an expansive network of radar sites and advanced computers. "The introduction of electronic high-speed digital computers capable of real-time information processing and of the 'command and control' of large-

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[2] Arnold, General Hap. Memorandum for General Spaatz; Subject: Future of Army Air Forces. Washington, D.C., 6 December 1945.
[3] Arnold, General Hap. Memorandum for General Spaatz; Subject: Future of Army Air Forces. Washington, D.C., 6 December 1945.
[4] Arnold, General Hap. Memorandum for General Spaatz; Subject: Future of Army Air Forces. Washington, D.C., 6 December 1945.
[5] Arnold, General Hap. Memorandum for General Spaatz; Subject: Future of Army Air Forces. Washington, D.C., 6 December 1945.

scale complex systems marks the major technological achievement of the SAGE Project."[6] Digital computation was the landmark technological development that led to the increased accuracy in inertial navigation efforts, forever changing space exploration and technological development.

Accurate inertial navigation was a precursor to future technological capabilities that have had a profound impact on society and warfare. However, in the early stages of development, the possibility of developing an effective inertial navigation capability was quite uncertain and suffered multiple missteps and problems throughout development. Inertial navigation's roots can be traced back to Germany's V2 program during World War II.

The goal for the early V2 program was to allow Germany to strike England with an unmanned missile accurately. This type of targeting approach is favorable to military applications because it is self-contained. In their use of inertial navigation, the Germans were able to allow for "the sensing of acceleration and changes in orientation by an inertial system that is achieved without use of external references: it is in an almost literal sense a black box."[7] During their use in World War II, the V2 was capable of striking within four miles of the desired target.[8] However, the largest contribution of the V2 and its operational employment was a shift in strategic thinking among industry and

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[6] Letter of transmittal for *Final Report of Project Charles,* quoted in Richard F. McMullen, *The Birth of Sage, 1951-1958,* Air Defense Research Command Historical Study no. 33, n.d.
[7] MacKenzie, Donald A. *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance*. (Cambridge: MIT Press, 1993), 16.
[8] H. H. Arnold. "*Air Force in the Atomic Age,"* in Dexter Masters and Katharine Way, eds., *One World or None* (New York: McGraw-Hill, 1946), 26-32.

academia. In the aftermath of World War II, many began to believe that inertial navigation was not only possible, but could also be extremely accurate.

As with other forms of technological development, inertial navigation was not guaranteed to succeed. Advances in technology have a better chance of success when they benefit vast portions of society. This is true for previous technologies such as the automobile or airplane. Inertial navigation found a willing partner in the aircraft industry. "The creation, stabilization, and growth of the air navigation inertial market played a major part in shaping technological innovation in inertial sensors."[9] The commercial aircraft industry allowed for engineers and scientists working on inertial navigation to provide a dual-use argument for both commercial and defense interests. This partnership created an environment which encouraged innovation and allowed technology to thrive and grow. As a result, "use of the power of the digital computer, sophisticated mechanical designs, and electro-optical technology to build more reliable and cheaper inertial systems has thus proven a sustainable technological trajectory."[10] As an effective business case for inertial navigation took shape, its applicability to other uses was apparent. Inertial navigation became critical to a new defense program, the Atlas Project.

Inertial navigation provided the accuracy in navigation needed for the Atlas Project. "Begun in 1954, the Atlas Project became the first of several projects that constituted an ICBM program culminating in the production of three missiles, the Atlas,

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[9] MacKenzie, Donald A. *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance*. (Cambridge: MIT Press, 1993), 179.
[10] MacKenzie, Donald A. *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance*. (Cambridge: MIT Press, 1993), 185.

the Titan, and the Minuteman."[11] Digital computing and accurate inertial navigation made the Atlas Project possible. As the Atlas Project progressed over time, the capabilities of digital computing continued to advance as well, allowing humans to change the nature of warfare. For instance, the last ICBM in the project, "Minuteman was equipped with an on-board digital computer: a general-purpose computer, not just the limited special-purpose 'digital calculator' used in Polaris."[12] This advancement provided the accuracy needed to target missile silos within the Soviet Union, providing American nuclear strategists with both counter-city and counter-force engagement options. The RAND Corporation, Arnold's vision for strategic partnerships with leading experts, developed strategies and implications for the employment of nuclear weapons using ICBMs. RAND strategies developed by Ernest Plesset, Charles Hitch, and Bernard Brodie are still applicable and still in use today in defense policy discussions. Digital computing and inertial navigation made these strategies possible. The next technological goal for humankind became space exploration and industry efforts greatly aided government investment in their efforts.

One such industry development effort came in the form of the Boeing X-20 Dyna-Soar.[13] The X-20 development began in 1959 and continued until 1963. It was originally "designed to be a 35.5-foot piloted reusable space vehicle, had a sharply swept delta 20.4-foot-span wing and a graphite and zirconia composite nose cap and used three

[11] Hughes, Thomas. *Rescuing Prometheus: Four Monumental Projects That Changed the Modern World*. (New York: Vintage Books, 2000), 69.
[12] MacKenzie, Donald A. *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance*. (Cambridge: MIT Press, 1993), 159.
[13] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.

retractable struts for landing. Eleven manned flights were to be launched from Cape Canaveral, Fla., starting in November 1964. Dyna-Soar's first orbital flight was tentatively scheduled for early 1965."[14] Ultimately, the program was cancelled in 1963 due to a lack of credible military missions. Technology in other fields hadn't matured to the point in which the platform could be utilized effectively. Despite its cancellation, the X-20 program had produced valuable research and development on the capabilities of a rapidly deployable space vehicle. At the time of its cancellation, "$410 million had been spent on its development, and a cadre of astronauts was training to fly it."[15] Funding for the X-20 program was shifted to invest in other areas of space development and exploration. One such program was with McDonnell Aircraft to build experimental aircraft to test the limits of flight in various parts of the atmosphere. Using knowledge from the X-20 program, "the scaled-down test vehicles were 5.7 feet long and used Douglas-built Thor or Thor-Delta boosters, which in turn used engines built by North American's Rocketdyne division. The program was very successful and demonstrated that winged reentry vehicles could traverse the upper atmosphere."[16] Industry development in space programs advanced a wide range of technologies applicable to space, particularly the development of advanced rockets used in the Apollo Program.

For many people, the Apollo Program and the quest for humans to venture to the moon remains one of the most remarkable achievements for humankind. When President Kennedy announced in 1962 that the United States would put a man on the moon by the end of the decade, the people of America had a clear goal, and tight timeline. As with

[14] Boeing Historical Snapshot provided by Boeing.com/history/products.
[15] Boeing Historical Snapshot provided by Boeing.com/history/products.
[16] Boeing Historical Snapshot provided by Boeing.com/history/products.

other technological projects, government, industry and academia were also crucial to success.[17] To achieve this goal for humankind, the best of emerging technologies combined with the best of modern aviation's piloting capabilities. The Apollo Program is representative of the fundamental debate of human-machine interaction in daily life and defense issues.

As with many aircraft, at the beginning of development efforts pilots were hesitant to trust computers to fly a spacecraft. They had little trust for complex computing systems that most did not understand and would rather place their fate in their own hands. Their opinions were not without merit. In 1964, NASA released its research regarding its first spacecraft, the X-15. In it, NASA stresses the importance of a pilot being able to override the controls of a spacecraft-type vehicle if necessary.[18] Other reports also note that multiple X-15 flights would have been lost without the presence of pilots on board to counter system malfunctions or manage emergency procedures. The Apollo Program decided to combine the best of what man had to offer in the form of reliability with the best of what digital computing had to offer in the form of rapid calculation and navigation.[19]

Autonomy and accuracy in the Apollo Program became the measurements of success that that are still evident in space exploration today.[20] These attributes led to the

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[17] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[18] United States Air Force. *X-15 Pilot-in-the-Loop and Redundant/Emergency Systems Evaluation.* Technical Documentary Report No. 62-20, Air Force Flight Test Center, Edwards Air Force Base, CA: Oct 1962.
[19] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[20] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.

decision to use a digital autopilot for the Apollo missions. Previous advances in digital computing, inertial navigation, and machine intelligence made this futuristic idea a reality. "The digital autopilot also confirmed the decision to use a general-purpose computer in the first place and underscored the intimate links between systems engineering and digital computing."[21] The results of these efforts were truly historic, culminating with a lunar landing.

Apollo 7 pushed digital computing further, spending over ten days in orbits and allowing engineers to garner valuable information to use in the Apollo program. Every step that the Apollo Program took was a historic first. The biggest success was the lunar landing of Apollo 11 in July of 1969 (the United States made President Kennedy's deadline that he established in 1962). During each mission, "hundreds of complex operations, but none were as demanding, time-critical, and plagued with uncertainties as the landing, executed in extreme conditions of darkness and cold, far from home."[22] Of note, "the autopilot took over the computer every tenth of a second for its calculations, which took about a fortieth of that time (twenty-five milliseconds) to complete."[23] For the first time in aviation history, a computer conducted more of the operations during a mission than the human did. Never one to be satisfied with success, the United States continued the Apollo Program, returning to the moon on multiple occasions through 1972. Apollo 12 was successful in fine-tuning precision landing capability, the one thing

[21] Mindell, David A. *Digital Apollo: Human and Machine in Spaceflight*. (Cambridge: MIT Press, 2008), 141.
[22] Mindell, David A. *Digital Apollo: Human and Machine in Spaceflight*. (Cambridge: MIT Press, 2008), 181.
[23] Mindell, David A. *Digital Apollo: Human and Machine in Spaceflight*. (Cambridge: MIT Press, 2008), 194.

that NASA sought to improve on from the Apollo 11 mission. Precision capability would become important for military operations and warfare in the future. At the same time that the Apollo missions were advancing space exploration, NASA's X-15 program was advancing and proving the technologies needed for the development of a rapid space vehicle.

NASA's Dryden Flight Research Center calls the X-15 program "the most successful aeronautical research effort in history."[24] Born in the aftermath of Germany's success with rockets during World War II, the X-15 was conceived in the 1950's with the vision of exploring the limits of speed and altitude in flight. The United States built the aircraft with two specific goals in mind. The first goal "was to achieve a speed of Mach 6, six times faster than the X-1 when it exceeded the speed of sound just a decade earlier. The other goal was to reach an altitude of 250,000 feet -- nearly 50 miles above the earth's surface, where there is no atmosphere to support wings and conventional control surfaces."[25] The X-15 program lasted for ten years and was able to achieve both of those stated goals. Ultimately, the X-15 flew to achieve a speed of Mach 6.7 (4,520 mph) and an altitude of 354,200 feet for a winged aircraft.[26] The X-15 is an aeronautical legend, rapidly achieving its program goals and changing the aeronautical world by blending traditional aviation in the atmosphere with manned space flight in a maneuverable space vehicle.

[24] NASA's Drydren Flight Research Center. https://www.nasa.gov/center/dryden
[25] NASA's Drydren Flight Research Center. https://www.nasa.gov/center/dryden
[26] NASA's Drydren Flight Research Center. https://www.nasa.gov/center/dryden

- “First glide flight; X-15 No. 1; June 8, 1959; pilot, Scott Crossfield, North American Aviation (NAA)
- First powered flight; X-15 No. 2; Sept. 17, 1959; pilot, Scott Crossfield, NAA
- First research flight; X-15 No. 1; Mar. 3, 1960; pilot, Joe Walker, NASA
- First flight with XLR-99 engine; X-15 No. 2; Nov. 15, 1960; pilot, Scott Crossfield, NAA
- Design speed; X-15 No. 2; Nov. 9, 1961; Mach 6.04 (4,093 mph); pilot, Robert White, USAF
- Design altitude; X-15 No. 1; Apr. 30, 1962 246,700 ft; pilot, Joe Walker
- First civilian flight above 50 miles; X-15 No. 3; Jan. 17, 1963; pilot, Joe Walker
- Unofficial world altitude record; X-15 No. 3; 354,200 ft; pilot, Joe Walker
- First flight with external tanks empty; X-15 No. 2; Nov. 3, 1965; pilot, Robert Rushworth, USAF
- First flight with external tanks full; X-15 No. 2; July 1, 1966; pilot, Robert Rushworth
- Unofficial world speed record; X-15 No. 2; Oct. 3, 1967; pilot, William Knight, USAF
- Last flight; X-15 No. 1; Oct. 24, 1968; pilot, Bill Dana, NASA”[27]

[27] NASA’s Drydren Flight Research Center. https://www.nasa.gov/center/dryden

Figure 2: An X-15, with landing skids and nose wheel down, nears the dry lakebed at Edwards AFB following a research flight, while accompanied by a NASA F-104 chase aircraft. (NASA Photo EC88-180-9)

Source: NASA’s Dryden Flight Research Center. https://www.nasa.gov/center/dryden

Figure 3: An X-15 hangs from a pylon beneath the right wing of NASA's B-52 carrier aircraft as the moment nears to drop the rocket-powered aircraft on a high-speed research flight (NASA Photo EC65-885)

Source: NASA’s Dryden Flight Research Center. https://www.nasa.gov/center/dryden

Figure 4: X-15 No. 2, with a dummy ramjet mounted on the lower ventral fin, is pictured at the beginning of a research flight following an air drop from NASA's B-52 carrier aircraft. (NASA Photo EC88-0180-2)

Source: NASA's Dryden Flight Research Center. https://www.nasa.gov/center/dryden

The technological advancements and lessons learned throughout the X-15 program directly impacted man's journey into space. NASA engineers were able to study how space impacted various materials used in different platforms. For instance, "as reaction control technology matured through the X-15 program and Projects Mercury, Gemini, and Apollo, refined systems were beginning to be used with increased frequency to stabilize and control orbiting satellites."[28] Each program being pursued by NASA, the United States Air Force, and civilian industry pushed previous limits to space flight and created a virtuous cycle in technological development. This virtuous cycle formed the basis in which space development and exploration moved forward. Most notably, the X-15 was the precursor for the development of NASA's Space Shuttle program.

Because of the Apollo and X-15 programs, the United States chose to develop a space plane that would later become the Space Shuttle. With its first flight in 1981,

[28] NASA's Drydren Flight Research Center. https://www.nasa.gov/center/dryden

NASA's Space Shuttle program became the focal point of manned space flight for decades and an alternate method for satellites to access orbit.[29] Made possible by digital computing, inertial navigation, and human-machine interaction, the Space Shuttle has allowed for a myriad of scientific research in space to include vast expanses in robotics.[30] For many, the members of the Apollo Program and its astronauts ushered in a new form of heroism in the human-machine field of technology. The lessons from Apollo in digital computing and human-machine interaction have grown to form new capabilities for the United States today. Digital computing and machine intelligence has created opportunities in the form of autonomous drone technology. International treaties and laws influence these advancements in technology and space vehicles.

One-hundred and two countries are a party to the 1967 Outer Space Treaty. An additional twenty-seven have signed, but not ratified, the treaty. Most countries and industries use this as the international standard for conduct in and through space. It uses the Antarctic Treaty as a model and seeks to "prevent 'a new form of colonial competition' and the possible damage that self-seeking exploitation might cause."[31] It begins by stating:

> Inspired by the great prospects opening up before mankind as a result of man's entry into outer space,
>
> Recognizing the common interest of all mankind in the progress of the exploitation and use of outer space for peaceful purposes,

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[29] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[30] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[31] United States Department of State. Comments regarding the Outer Space Treaty. Signed in Washington D.C., London, and Moscow, 27 Jan 1967.

> Believing that the exploitation and use of outer space should be carried on for the benefit of all peoples irrespective of the degree of their economic or scientific development,
>
> Desiring to contribute to broad international co-operation in the scientific as well as legal aspects of the exploitation and use of outer space for peaceful purposes,
>
> Believing that such co-operation will contribute to the development of mutual understanding and to the strengthening of friendly relations between States and peoples…[32]

This introduction undeniably sets forth the understanding for all parties to the treaty that space should be for peaceful purposes for each nation and all mankind. The treaty references resolution 1884 which calls "upon States to refrain from placing in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction or from installing such weapons on celestial bodies."[33] Article IV of the Outer Space Treaty goes on to outline this in detail by saying, "States Parties to the Treaty undertake not to place in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, install such weapons on celestial bodies, or station such weapons in outer space in any other manner."[34] Article IV has remarkable implications for the future of airpower and spacepower theory and strategy.

The language that the signatories use in Article IV is lacking for the modern era. In 1967, the entities capable of space launch and exploration were clearly defined

[32] United States Department of State. Outer Space Treaty. Signed in Washington D.C., London, and Moscow, 27 Jan 1967.
[33] United States Department of State. Outer Space Treaty. Signed in Washington D.C., London, and Moscow, 27 Jan 1967.
[34] United States Department of State. Outer Space Treaty. Signed in Washington D.C., London, and Moscow, 27 Jan 1967.

sovereign states. Currently, this model has reversed itself with private industry leading the space development and exploration efforts around the world. This is not surprising considering the treaty is 50 years old. This fact, however, is representative of how emerging technology will push both national and international policy decisions, as well as treaties to change in comparison to historical models.

Article IV also forbids states from placing nuclear weapons or other weapons of mass destruction in orbit. The intent of this article concerns the potential destabilizing effects that weapons of mass destruction could bring to the world from space. Conversations with *A Rapid Global Effects Capability Concept Wargame* participants over the last two years brought up this concern as well regarding the military implications of lowering the cost to access space.[35]

Participants in the wargame recommended against using military capabilities in space for nuclear weapons, component, or material transportation or employment.[36] Their main justification was the destabilizing effects they believed such a step would take in the international policy arena. However, they did caution that the United States should continue to pursue such technology and have the capability to rapidly employ nuclear weapons with a rapid space launch capability if the national security of the United States required it. For instance, if a near-peer adversary were to show the intent to develop that capability, the United States could not afford to let the adversary develop the capability uncontested.

[35] LeMay Center Wargaming Directorate. *A Rapid Global Effects Capability Concept Wargame After Action Report.* Maxwell Air Force Base, AL, 22 October 2015.
[36] LeMay Center Wargaming Directorate. *A Rapid Global Effects Capability Concept Wargame After Action Report.* Maxwell Air Force Base, AL, 22 October 2015.

If the United States chose to further develop its Experimental Spaceplane (XS-1), it would differ considerably from conventional Inter-Continental Ballistic Missiles and the Ground Based Strategic Deterrent. It has the potential for both conventional and nuclear mission applications. Also, depending on the choices made in development, it has the potential to be a highly mobile asset.[37] Ultimately, if a rapid launch capability is chosen to support a nuclear mission, it would offer the United States options in addition to the nuclear triad.[38] For instance, investing in new nuclear-capable platforms or re-investing in Cold War era capabilities would be a strategic dilemma.[39] In an era when the United States is investing heavily in the revitalization of its nuclear force, this warrants consideration.[40]

Concerning Article IV, an XS-1 type vehicle is within the international norm for the delivery of nuclear weapons or weapons of mass destruction. This is due to the fact that the capability would transit space (low earth orbit) in order to deliver the munitions. It would not place a nuclear weapon or weapon of mass destruction into orbit. Further, Article IV "allows fractional orbital bombardment systems (FOBS), a 1960s Soviet ICBM program that after launch would go into a low Earth orbit and would then de-orbit

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[37] Akhadov, Elshan. Interview conducted at Los Alamos National Laboratory. Los Alamos, NM, 14 Oct 15.
[38] LeMay Center Wargaming Directorate. *A Rapid Global Effects Capability Concept Wargame After Action Report.* Maxwell Air Force Base, AL, 22 October 2015.
[39] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[40] Akhadov, Elshan. Interview conducted at Los Alamos National Laboratory. Los Alamos, NM, 14 Oct 15

for an attack."[41] Thus, research suggest that an XS-1 vehicle meets the obligations of the Outer Space Treaty.

Article VI states, "States Parties to the Treaty shall bear international responsibility for national activities in outer space, including the Moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty."[42] This article impacts both external and internal policy of the United States.

The United States government is responsible for the actions of industry leaders such as SpaceX and Blue Origin in their pursuit of space exploration and development. For instance, if a private industry rocket launch damages a nation's satellite after being launched, the United States is responsible. If private companies begin asteroid mining,[43] the United States government is responsible for their regulation and protection. Article VI, however, is lacking in modern economic practices. Considering the developments in communications and the global nature of large companies, Article VI needs updating. For instance, a company can be headquartered in the United States, launch assets into space from Australia, control those assets from an island that is part of Great Britain, and use a team of professionals from a wide range of countries to accomplish their objectives. In this modern-day scenario, Article VI is lacking in defining responsibilities. That being

[41] Sercel, Joel. *Sub-Orbital Transport, Air Force Guardian Program Concept Initial Feasibility Analysis.* ICS Associates Inc., 2016.
[42] United States Department of State. Outer Space Treaty. Signed in Washington D.C., London, and Moscow, 27 Jan 1967.
[43] Colby, Elbridge. *The Implications of the Commercialization of Space and ULCATS for a U.S. Limited War Defense and Deterrence Strategy for Space.* Washington, D.C.: Center for a New American Security, Nov 16.

said, if international treaties bound the United States to bear responsibility for their industries' actions, it would be prudent to have the capability to do so. A rapid launch capability and the technology related to it would help the United States meet their treaty obligations. The capability to launch into space rapidly ensures that the United States can protect and regulate interests in space.

Article VII further outlines international responsibility when it states, "Each State Party to the Treaty that launches or procures the launching of an object into outer space, including the Moon and other celestial bodies, and each State Party from whose territory or facility an object is launched, is internationally liable for damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth, in air space or in outer space, including the Moon and other celestial bodies."[44] Clearly, the United States government has a responsibility to be involved in the governing of developing space-related technology as well as the regulation of space exploration in the industrial sector. As with Article VI, Article VII is outdated concerning the nature of modern-day international business as well as evolving military capabilities in space.

Article X states, "In order to promote international co-operation in the exploration and use of outer space, including the Moon and other celestial bodies, in conformity with the purposes of this Treaty, the States Parties to the Treaty shall consider on a basis of equality any requests by other States Parties to the Treaty to be afforded an opportunity to observe the flight of space objects launched by those States. The nature of such an

[44] Colby, Elbridge. *The Implications of the Commercialization of Space and ULCATS for a U.S. Limited War Defense and Deterrence Strategy for Space.* Washington, D.C.: Center for a New American Security, Nov 16.

opportunity for observation and the conditions under which it could be afforded shall be determined by agreement between the States concerned."[45] Due to the fact that the Outer Space Treaty determines that states are responsible for their industries actions in space, this presents an interesting dilemma. Could adversaries to the United States require private United States companies to provide sensitive information to meet treaty obligations? What constitutes observing the flight of space objects? Could adversaries invoke Article X and request to observe the private industry launches of SpaceX or Blue Origin? By being able to observe space objects launched from the United States, adversaries are better able to target those objects. This has deep implications on the military applications of space launch. As space exploration and development continues, defense related space systems will require maneuverability and speed in order to defeat adversary's observations in accordance with Article X.

Article XI states, "In order to promote international co-operation in the peaceful exploration and use of outer space, States Parties to the Treaty conducting activities in outer space, including the Moon and other celestial bodies, agree to inform the Secretary-General of the United Nations as well as the public and the international scientific community, to the greatest extent feasible and practicable, of the nature, conduct, locations and results of such activities."[46] This article has profound implications for external policy considerations. If a private company discovers valuable minerals on a

[45] Colby, Elbridge. *The Implications of the Commercialization of Space and ULCATS for a U.S. Limited War Defense and Deterrence Strategy for Space.* Washington, D.C.: Center for a New American Security, Nov 16.
[46] Colby, Elbridge. *The Implications of the Commercialization of Space and ULCATS for a U.S. Limited War Defense and Deterrence Strategy for Space.* Washington, D.C.: Center for a New American Security, Nov 16.

celestial body, the United States is bound by the Outer Space Treaty to make that information public, reporting it to both the United Nations and scientific community. This, in turn, will produce a rush in the international community to mine these minerals similar to gold rushes around the world throughout history. Again, the United States is bound by international treaty to regulate private industries based out of the United States. It would be prudent to have the space launch capability to enforce international treaties and laws in space.[47] This could be accomplished with either a policing function in a capacity similar to the United States Coast Guard.[48]

Decreasing the cost to access space and a rapid launch capability, such as via the XS-1, would have vast implications for accessing the space domain. Not only would it provide the capability to influence traditional military operations on Earth, it would also provide the United States with rapid access to space as well.[49] As technologies emerge that can influence space operations, having the capability to rapidly deploy assets such as Cubesats would be highly beneficial. This allows for the reconstitution of compromised traditional satellites.[50] Also, the ability to cheaply and rapidly access space would allow

[47] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[48] Dolman, Everett C. *Astropolitik: Classic Geopolitics in the Space Age*. (London: Frank Cass, 2002) 30.
[49] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[50] Akhadov, Elshan. Interview conducted at Los Alamos National Laboratory. Los Alamos, NM, 14 Oct 15

for the deployment of personnel to space or equipment for mining operations.[51] The deployment of personnel would help enforce international treaties and laws in space.[52]

The Outer Space Treaty encourages the efforts of decreasing the cost to access space and subsequently the development of a rapid launch capability to exploit space. The Outer Space Treaty even allows for weapons transport and delivery as long as those weapons are not nuclear or considered weapons of mass destruction. The broader external policy implications come with the development of emerging technologies that will push the United States and international community into space. The United States will be responsible for the industrial base within the United States and their actions. As a result, the United States will need the capability to respond to challenges within and through space. The Strategic Arms Limitation Talks and Strategic Arms Reduction Treaty will also influence future United States policy.

The Strategic Arms Limitation Talks "banned FOBS or any significant advancement in ICBM key performance parameters, but was not ratified by the U.S. due to other Soviet treaty violations."[53] However, SALT-II was traditionally honored by both the United States and Soviet Union. SALT-II has been replaced with the "Strategic Arms Reduction Treaty (START), Comprehensive Nuclear-Test-Ban Treaty, and New START which has been ratified and is applicable through 2021."[54] Currently, these treaties

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[51] Colby, Elbridge. *The Implications of the Commercialization of Space and ULCATS for a U.S. Limited War Defense and Deterrence Strategy for Space.* Washington, D.C.: Center for a New American Security, Nov 16.
[52] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[53] Sercel, Joel. *Sub-Orbital Transport, Air Force Guardian Program Concept Initial Feasibility Analysis.* ICS Associates Inc., 2016.
[54] Sercel, Joel. *Sub-Orbital Transport, Air Force Guardian Program Concept Initial Feasibility Analysis.* ICS Associates Inc., 2016.

prevent both the United States and Russia from pursing the development of FOBS systems. These treaties do not "address conventional weapons in space, orbital or suborbital; however, the range and capability of carrier systems such as cruise missiles that could carry nuclear arms are limited….but not the manned aircraft that carry them."[55]

Decreasing the cost to access space and the development of rapid launch vehicles is allowable according to the New START treaty and is in line with the historical framework of previous treaties such as SALT-II. According to the framework of the New START treaty, it is beneficial for space vehicles to be manned platforms if the United States is interested in having the option to have a nuclear capability. If the United States chooses to focus on conventional capabilities, this provides an opportunity for enhanced human-machine operations or remotely piloted options.

Due to current treaties, it is also important to understand at what altitude space begins. A nation's sovereign territory includes the airspace above it. However, it does not include the "space" above it. The Karman Line is at an altitude of 100 km above the Earth's surface. It "represents the boundary between the Earth's atmosphere and outer space according to the Federation Aeronautique Internationale (FAI), an international standard setting and record-keeping body for aeronautics and astronautics."[56] At this altitude, an aircraft or space vehicle has to "fly faster than orbital velocity to have enough

[55] Sercel, Joel. *Sub-Orbital Transport, Air Force Guardian Program Concept Initial Feasibility Analysis.* ICS Associates Inc., 2016.
[56] Sercel, Joel. *Sub-Orbital Transport, Air Force Guardian Program Concept Initial Feasibility Analysis.* ICS Associates Inc., 2016.

lift to overcome drag."[57] However, it is important to note that this is not international law, nor is it included in any international treaties.

The United States has "consistently maintained that discussions of delimitation between air and outer space are premature and advocates the removal of delimitation from the agenda of the Legal Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space."[58] The current international standard is that airspace below 100 km is a nation's sovereign territory and above 100 km is international space.[59] This allows nations to place satellites, launch rockets, or space vehicles in any orbit. Decreasing the cost to access space will allow space vehicles to utilize low earth orbit, meeting the current international standards and would not violate other nation's sovereign territory or airspace. The United States' legal viewpoint and participation in various treaties has its roots in the post-World War II international environment and is reflected in its strategic investments over the last 60 years.

[57] Sercel, Joel. *Sub-Orbital Transport, Air Force Guardian Program Concept Initial Feasibility Analysis.* ICS Associates Inc., 2016.
[58] Sercel, Joel. *Sub-Orbital Transport, Air Force Guardian Program Concept Initial Feasibility Analysis.* ICS Associates Inc., 2016.
[59] Sercel, Joel. *Sub-Orbital Transport, Air Force Guardian Program Concept Initial Feasibility Analysis.* ICS Associates Inc., 2016.

Chapter 4

Space Industry Research and Development

As air, space, and military theory continue to evolve, humankind has begun to view its historical efforts in space access in different ways. This evolution of thought has inspired a renewed interest in space industry research and development. Due to this shift, the Department of Defense and commercial industry are currently conducting technological research applicable to lowering the cost to access space. Commercial investment has led to an environment in which the Technology Readiness Levels (TRLs) of the technology needed to field a rapidly launched, reusable space vehicles is achievable.[1] "Technology Readiness Levels (TRL) are a type of measurement system used to assess the maturity level of a particular technology. Each technology project is evaluated against the parameters for each technology level and is then assigned a TRL rating based on the project's progress. There are nine technology readiness levels, with TRL 1 being the lowest and TRL 9 the highest."[2] The technology readiness levels for the technologies currently in research are at a TRL 5 or above.[3] According to NASA, "once the proof-of-concept technology is ready, the technology advances to TRL 4. During TRL 4, multiple component pieces are tested with one another. TRL 5 is a continuation of 4, however, a technology that is at 5 is identified as a breadboard technology and must undergo more rigorous testing than technology that is only at TRL 4."[4] Using technologies that are already being developed allows for government investment later in

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[1] Miller, Charles. Comments made at the Pentagon during A Rapid Global Effects Capability meeting. Washington D.C., 7 Dec 15.
[2] Mui, Thuy. *Technology Readiness Level.* NASA, 28 Oct 12.
[3] Sponable, Jess. Comments made at Air University. Maxwell AFB, AL, 22 Feb 16.
[4] Mui, Thuy. *Technology Readiness Level.* NASA, 28 Oct 12.

the development process, thus cutting overall acquisition and costs to the U.S. government.[5] Companies such as United Launch Alliance, SpaceX, Blue Origin, and Masten Space Systems are conducting similar research and development.[6]

The United Launch Alliance (ULA) was formed in 2006 through a joint venture between the Boeing Company and the Lockheed Martin Corporation. Their stated goal is to combine "the production, engineering, test and launch operations associated with U.S. government launches of Boeing Delta and Lockheed Martin Atlas rockets - providing world-class space launch services for the U.S. government at lower cost."[7] By combining their teams, these two companies brought together some of the leading experts in rocket propulsion technology and space exploration. Their individual programs, Atlas and Delta, have had a historical presence in space for the United States.[8] Their customers have included private industry partners, government agencies, the Department of Defense, and NASA.[9]

The Atlas and Delta programs have been highly successful in support of these organizations.[10] These "expendable launch vehicles have supported America's presence in space for more than 50 years, carrying a variety of payloads including weather,

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[5] Secure World Foundation Panel. Comments by Mr. Kenneth Hodgkins, Director, Office of Space and Advanced Technology, U.S. Department of State. Washington D.C., 5 May 2016.
[6] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[7] United Launch Alliance. http://www.ulalaunch.com/about-ula.aspx
[8] Miller, Charles. Comments made at the Pentagon during A Rapid Global Effects Capability meeting. Washington D.C., 7 Dec 15.
[9] Avery, Greg. *NASA adds 8 space station missions, bringing more launches to ULA.* Denver, CO: BizJournal, 3 Jan 17.
[10] United States Air Force. *Military Spaceplane, Generating and Executing Combat Spacepower; Results of the AF-NASA 120 Day Study on RLV.* Washington, D.C.: Office of the Secretary of the Air Force, 2002.

telecommunications and national security satellites that protect and improve life on Earth, as well as deep space and interplanetary exploration missions that further our knowledge of the universe."[11] The Atlas V, Delta II, and Delta IV launch vehicles are developed, maintained, and launched in locations across the United States.

With a goal of providing 100 percent mission success and persistent access to space, ULA has developed a large infrastructure to support its launches. A team of over 3,400 people support the company in a wide range of activities from pre-mission planning and business development to launch operations and command and control. ULA headquarters are located in Denver, Colorado; most of its manufacturing occurs in Decatur, Alabama and Harlingen, Texas; and it conducts launch operations at both Cape Canaveral Air Force Station, Florida, and Vandenberg Air Force Base, California.[12] Over the course of their operation, "Atlas and Delta have launched approximately 1,300 missions"[13] and continue to be used today.[14] Recent ULA news releases highlight how active the company is.

On January 20th, 2017, ULA was in the news for their support of the United States national space efforts. A ULA Atlas V rocket was used to carry the Space Based Infrared System (SBIRS) GEO Flight 3 satellite into orbit.[15] The SBIRS GEO Flight 3 is critical to the nation's decision makers, providing key surveillance capability for the United

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[11] United Launch Alliance. http://www.ulalaunch.com/about-ula.aspx
[12] Spaceflight Insider. http://www.spaceflightinsider.com/launch-schedule/
[13] United Launch Alliance. http://www.ulalaunch.com/about-ula.aspx
[14] Miller, Charles. Comments made at the Pentagon during A Rapid Global Effects Capability meeting. Washington D.C., 7 Dec 15.
[15] Knightly, Paul. *Inauguration Day Atlas V Launch Sends National Security Satellite to Space.* Spaceflight Insider, 20 Jan 17.

States.[16] It has four mission areas critical to national security: “missile warning, missile defense, technical intelligence, and battlespace awareness.”[17] ULA Vice-President of Government Satellite Launch, Laura Maginnis, said of the launch, “ULA is proud to deliver this critical satellite which will improve surveillance capabilities for our national decision makers.”[18]

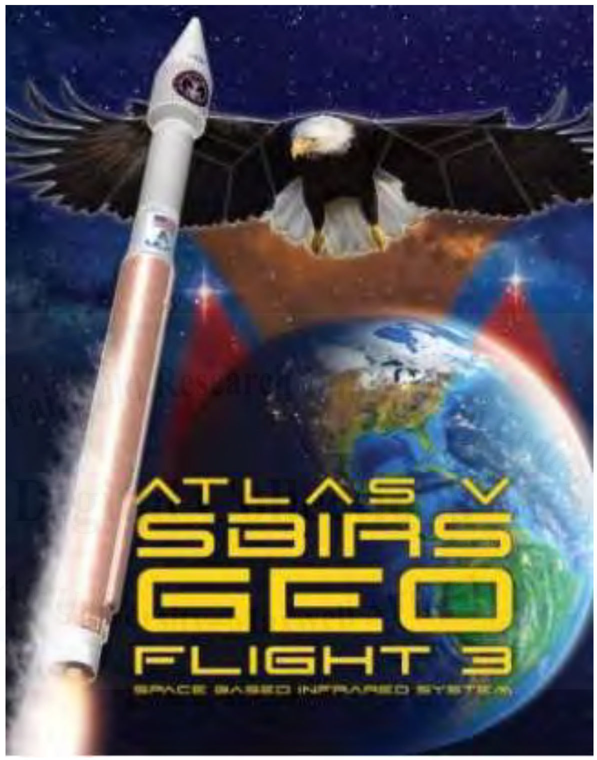

Figure 5: SBIRS Atlas V Artword

Source: (ULA and NRO Design from http://www.ulalaunch.com/news-press.aspx?Category=News)

[16] Knightly, Paul. *Inauguration Day Atlas V Launch Sends National Security Satellite to Space.* Spaceflight Insider, 20 Jan 17.
[17] Knightly, Paul. *Inauguration Day Atlas V Launch Sends National Security Satellite to Space.* Spaceflight Insider, 20 Jan 17.
[18] Knightly, Paul. *Inauguration Day Atlas V Launch Sends National Security Satellite to Space.* Spaceflight Insider, 20 Jan 17.

While this was the first launch of 2017, ULA accomplished other launches on March 1, 2017 and March 18, 2017. During the March 1, 2017 launch, ULA will use an Atlas V launch vehicle will support the National Reconnaissance Office in its NROL-79 mission.[19] This launch "will mark the 70th Atlas V launch and the 35th in the 401 configuration since the rocket's inaugural mission in 2002."[20] During the March 18, 2017 launch, ULA will use Delta IV launch vehicle to deliver a "WGS-9 satellite for the U.S Air Force"[21] from Cape Canaveral Air Force Station, Florida. Thus far, ULA has had "116 successful launches since the company was formed in December 2006."[22]

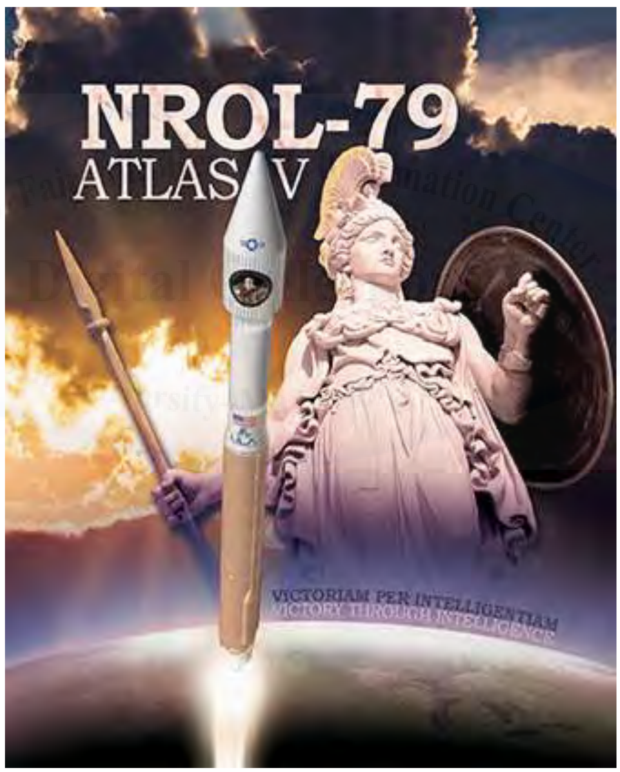

Figure 6: NROL-79 Atlas V Artword

Source: (ULA and NRO Design from http://www.ulalaunch.com/news-press.aspx?Category=News)

[19] Richardson, Derek. *Atlas V Sends Classified NROL-79 Payload to Space.* Spaceflight Insider, 1 March 17.
[20] United Launch Alliance. http://www.ulalaunch.com/news-press.aspx?Category=News
[21] Leahy, Bart. *Delta IV Launches WGS-9 to Expand Defense Communications.* Spaceflight Insider, 18 March 17.
[22] United Launch Alliance. http://www.ulalaunch.com/news-press.aspx?Category=News

The success of both the Boeing Company and the Lockheed Martin Corporation's space programs, and now ULA, is due to their Atlas and Delta families of launch vehicles.[23] Utilizing a continuous improvement approach, the Atlas V is an improved version of the previously flown Atlas I, II, and III vehicles, as well as the Titan. The Atlas V provides medium to heavy-lift capability for a wide range of U.S. government and commercial launch parties.[24] To date, the Atlas V has had a 100 percent success rate. ULA credits this achievement to their incremental approach to continuous process improvement. "Built modularly with flight-proven elements, Atlas V has followed a carefully executed program of incremental improvements"[25] that has proven successful in over 600 launches.

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[23] Miller, Charles. Comments made at the Pentagon during A Rapid Global Effects Capability meeting. Washington D.C., 7 Dec 15.
[24] SpaceToday. http://www.spacetoday.org/Rockets/Delta4_Atlas5.html#Atlas
[25] United Launch Alliance. http://www.ulalaunch.com/products.aspx

Figure 7: Atlas V Series of Launch Vehicles

Source: (ULA Design from http://www.ulalaunch.com/products.aspx)

The current versions of the Atlas V launch vehicle are the Atlas V 400 and Atlas V 500 series.[26] The Atlas V 400 and 500 series use "a standard common core booster™ (CCB), up to five strap-on solid rocket boosters (SRB), an upper-stage Centaur in either the Single-Engine Centaur (SEC) or the Dual-Engine Centaur (DEC) configuration, and one of several payload fairings (PLF)."[27][28] The Atlas V 400 series uses the "flight proven 4-m diameter 12.0 m (39.3 ft) large payload fairing (LPF), the 12.9 m (42.3 ft) extended

[26] Harrison, Todd, Hunter, Andrew, Johnson, Kaitlyn, and Roberts, Thomas. *Implications of Ultra-Low Cost Access to Space.* Washington, D.C.: Center for Strategic and International Studies, Feb 2017.
[27] United Launch Alliance. http://www.ulalaunch.com/products.aspx
[28] Spaceflight Insider. http://www.spaceflightinsider.com/hangar/atlas-v/

payload fairing (EPF), or the 13.8 m (45.3 ft) extended EPF (XEPF)."[29][30] The Atlas V 500 series uses the "flight-proven 5-m diameter 20.7 m (68 ft) short, the 23.5 m (77 ft) medium, or the 26.5 m (87 ft) long payload fairing."[31][32]

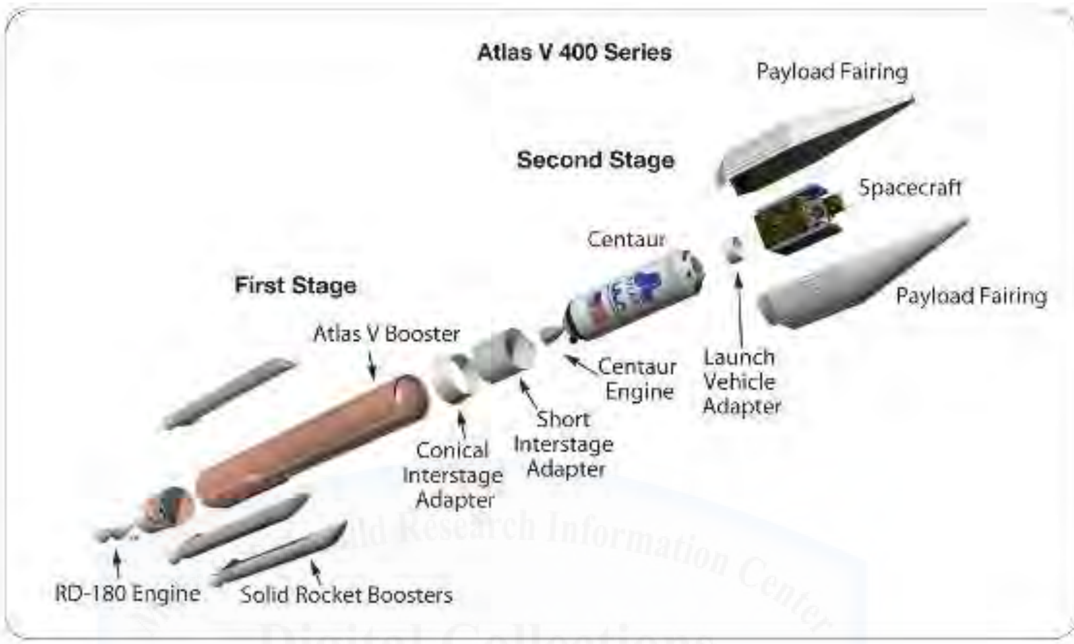

Figure 8: Atlas V 400 Series of Launch Vehicles

Source: (ULA Design from http://www.ulalaunch.com/products.aspx)

[29] United Launch Alliance. http://www.ulalaunch.com/products.aspx
[30] Spaceflight Insider. http://www.spaceflightinsider.com/hangar/atlas-v/
[31] United Launch Alliance. http://www.ulalaunch.com/products.aspx
[32] Spaceflight Insider. http://www.spaceflightinsider.com/hangar/atlas-v/

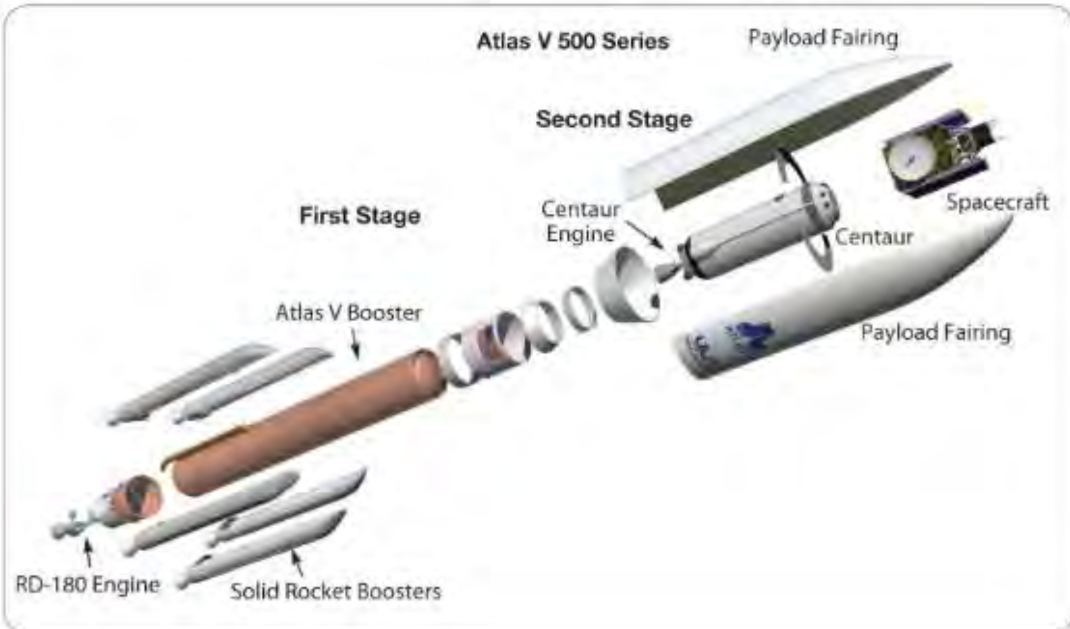

Figure 9: Atlas V 500 Series of Launch Vehicles

Source: (ULA Design from http://www.ulalaunch.com/products.aspx)

Payload Fairings

Payload fairings provide an environment for cargo transportation. Payloads such as satellites or communications equipment can be stored in these controlled environments and sheltered from the effects of launch and delivery, ensuring their safe deployment. "The Atlas V large payload fairing (LPF), extended payload fairing (EPF), and extended EPF (XEPF) have a common 4-m diameter cylindrical section topped by a conical section."[33][34] There are various payload fairing options to accommodate a range of payload sizes.[35] During the lead up to a launch, payloads are loaded within payload fairings away from the launch pad to ensure the safest possible operation.

[33] United Launch Alliance. http://www.ulalaunch.com/products.aspx
[34] Spaceflight Insider. http://www.spaceflightinsider.com/hangar/atlas-v/
[35] Miller, Charles. Comments made at the Pentagon during A Rapid Global Effects Capability meeting. Washington D.C., 7 Dec 15.

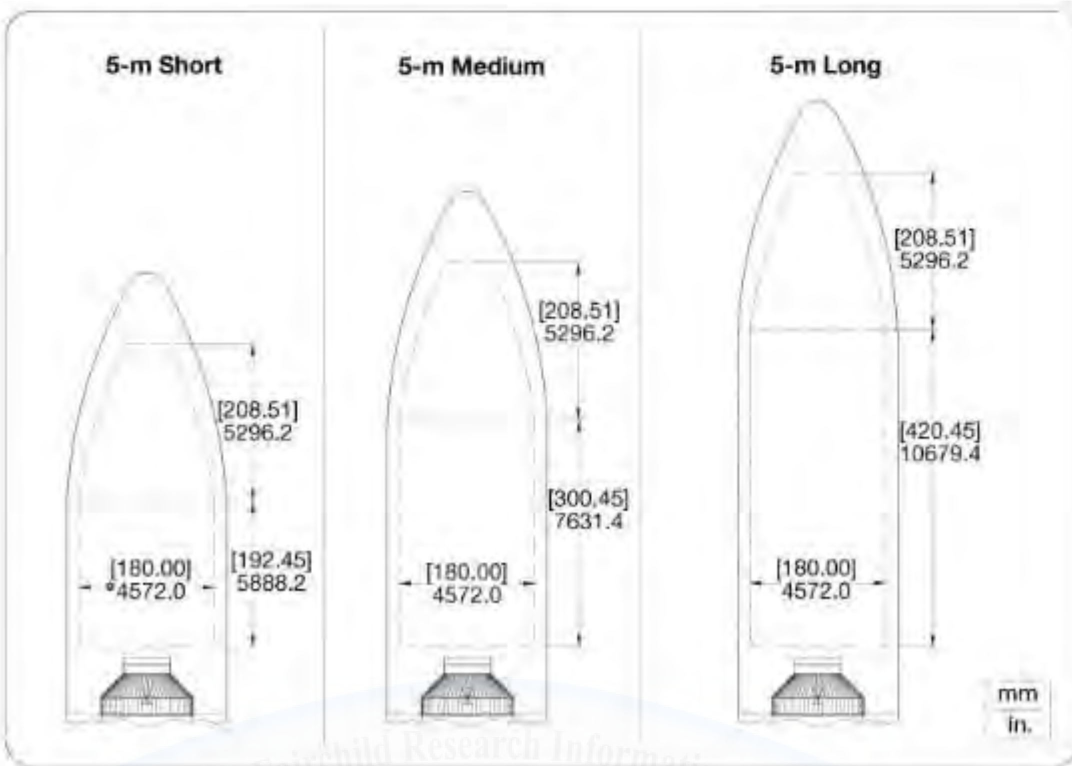

Figure 10: 5-m Short, Medium, and Long Payload Fairings

Source: (ULA Design from http://www.ulalaunch.com/products.aspx)

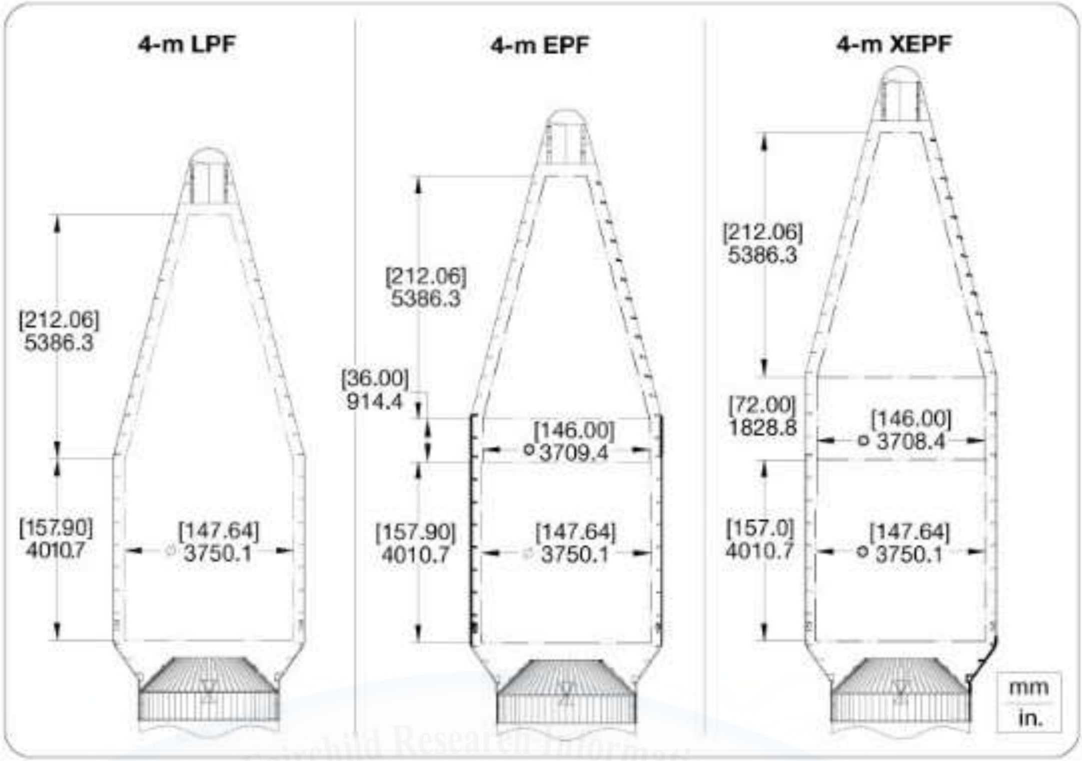

Figure 11: 4-m Long, Extended, and Extended EPF

Source: (ULA Design from http://www.ulalaunch.com/products.aspx)

The Delta series of launch vehicles trace their roots to the Thor intermediate-range ballistic missile that the U.S. Air Force employed in the 1950s.[36] The Thor was modified into what is today known as the Delta II. The Delta II has also evolved into the Delta IV with the help of the U.S. Air Force's Evolved Expendable Launch Vehicle program. The Delta IV "blends advanced and proven technology to launch virtually any size medium-to-heavy class payload to space."[37] Both the Delta II and Delta IV launch vehicles remain in use today.[38]

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[36] Miller, Charles. Comments made at the Pentagon during A Rapid Global Effects Capability meeting. Washington D.C., 7 Dec 15.
[37] United Launch Alliance. http://www.ulalaunch.com/products.aspx
[38] Spaceflight Insider. http://www.spaceflightinsider.com/hangar/delta-iv/

The Delta II entered service in 1989 and has become a centerpiece of space delivery for the United States.[39] It has "launched a multitude of payloads for customers within the United States and around the world including interplanetary satellites for NASA; Global Positioning System (GPS) satellites for the U.S. Air Force (USAF); research and development satellites for the National Reconnaissance Office (NRO), Defense Advanced Research Projects Agency (DARPA) payloads; Missile Defense Agency (MDA) payloads; Earth-observing, science, and communication and imaging satellites for various commercial and international customers."[40]

The Delta II has also created opportunities for non-governmental organizations such as universities to use space available during primary launches, known as ridesharing.[41] The Delta II is composed of a "first stage with its graphite-epoxy motor (GEM) solid strap-on rocket motors, the second stage, and the payload fairing (PLF)."[42]

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39 United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
40 United Launch Alliance. http://www.ulalaunch.com/products.aspx
41 Miller, Charles. Comments made at the Pentagon during A Rapid Global Effects Capability meeting. Washington D.C., 7 Dec 15.
42 United Launch Alliance. http://www.ulalaunch.com/products.aspx

Figure 12: Delta II Series of Launch Vehicles

Source: (ULA Design from http://www.ulalaunch.com/products.aspx)

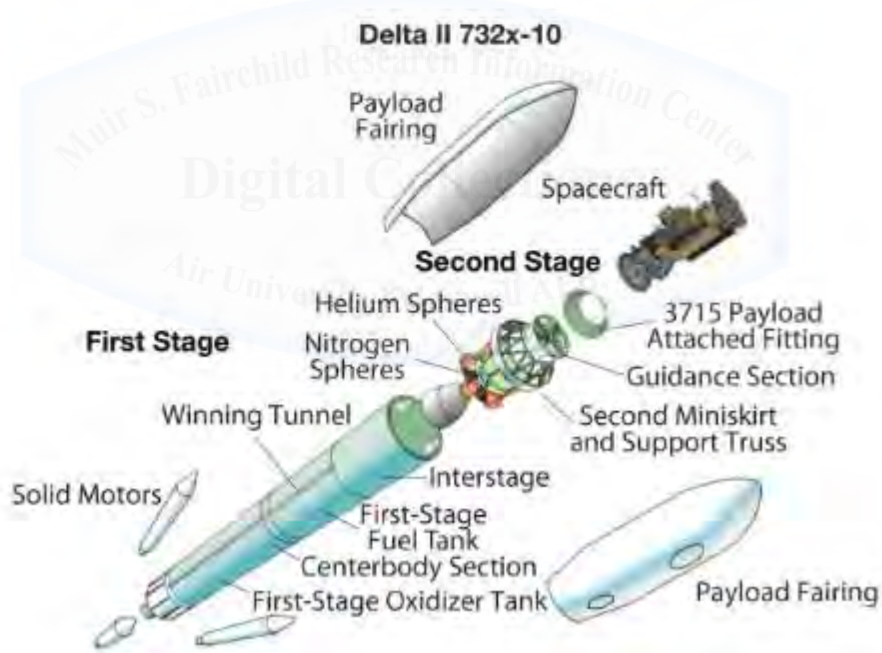

Figure 13: Delta II 732x-10 Launch Vehicle

Source: (ULA Design from http://www.ulalaunch.com/products.aspx)

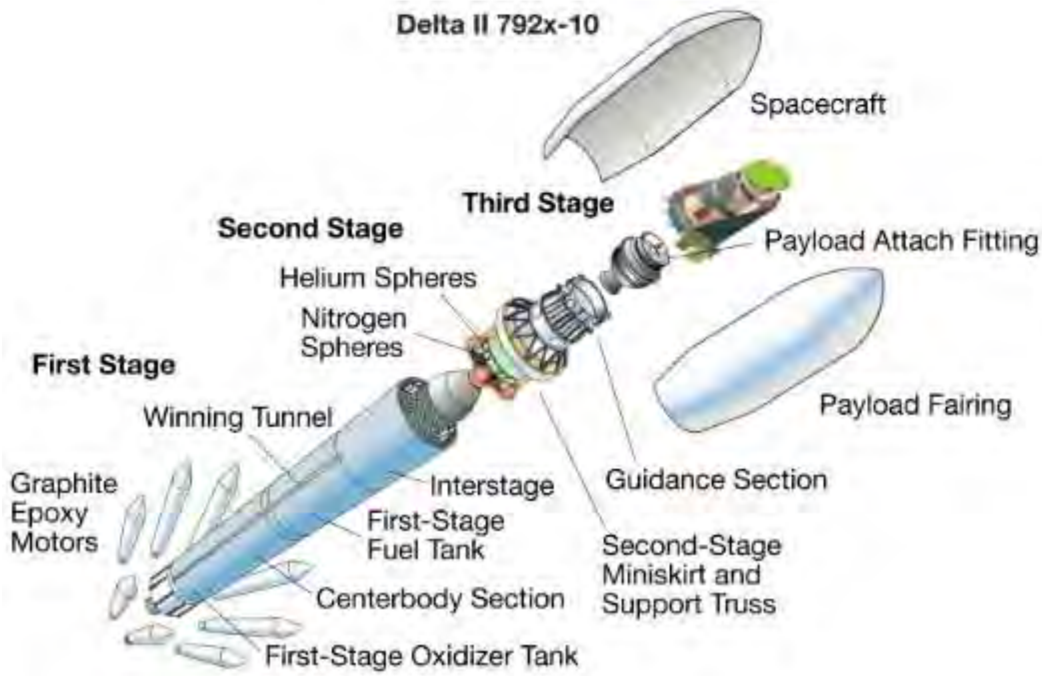

Figure 14: Delta II 792x-10 Launch Vehicle

Source: (ULA Design from http://www.ulalaunch.com/products.aspx)

Payload Fairings

The Delta II offers similar payload fairings to the Atlas V.[43] The Delta II "offers the user a choice of three fairings: a 2.9-m (9.5-ft)-diameter skin-and-stringer center section fairing (bisector), and two versions of a 3-m (10-ft)-diameter (bisector) composite fairing with two different lengths."[44] As with the Atlas V, the different payload pairings accommodate different volumes of payload. [45]

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[43] Miller, Charles. Comments made at the Pentagon during A Rapid Global Effects Capability meeting. Washington D.C., 7 Dec 15.; United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[44] United Launch Alliance. http://www.ulalaunch.com/products.aspx
[45] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.

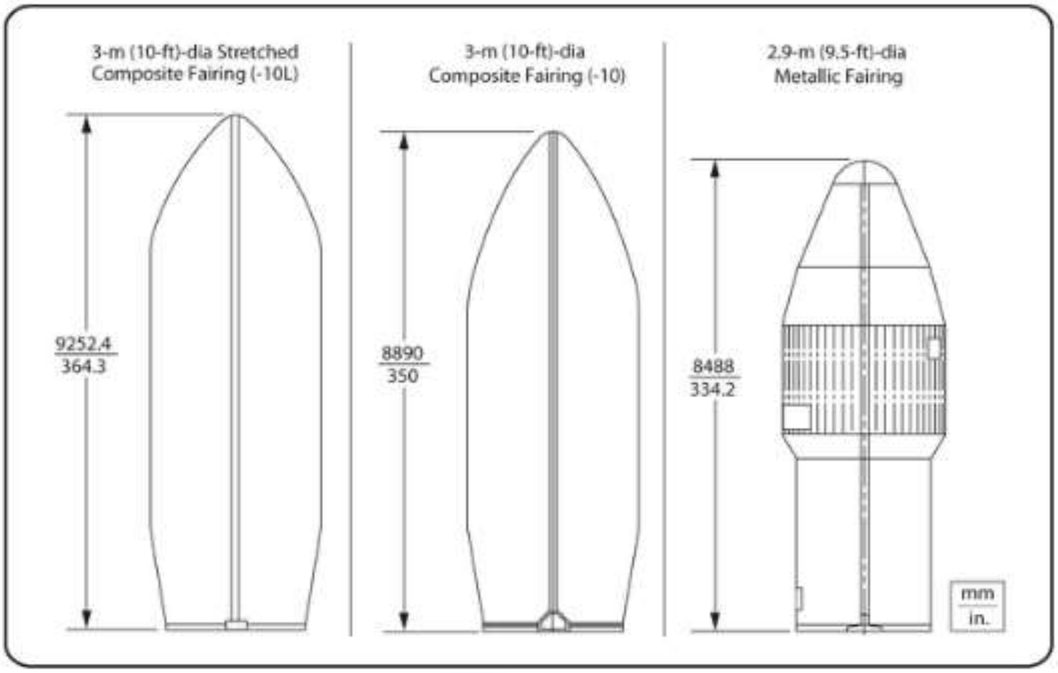

Figure 15: 3-m Stretched Composite, Composite, and Metallic Fairing

Source: (ULA Design from http://www.ulalaunch.com/products.aspx)

The Delta IV series of launch vehicles is a natural evolution of the Delta II.[46] Based out of both coasts in the United States, it offers a greater flexibility in launch operations to meet user demands. "The Delta IV launch system is available in five configurations: the Delta IV Medium (Delta IV M), three variants of the Delta IV Medium-Plus (Delta IV M+), and the Delta IV Heavy (Delta IV H). Each configuration is comprised of a common booster core (CBC), a cryogenic upper stage and either a 4-m-diameter or 5-m-diameter payload fairing (PLF)."[47][48] The Delta IV comes is available in

46 Miller, Charles. Comments made at the Pentagon during A Rapid Global Effects Capability meeting. Washington D.C., 7 Dec 15.
47 United Launch Alliance. http://www.ulalaunch.com/products.aspx
48 Spaceflight Insider. http://www.spaceflightinsider.com/hangar/delta-iv/

three different configurations: Delta IV M+ (4,2), Delta IV M+ (5,2), and Delta IV M+ (5,4).[49]

Figure 16: Delta IV Series of Launch Vehicles

Source: (ULA Design from http://www.ulalaunch.com/products.aspx)

[49] Spaceflight Insider. http://www.spaceflightinsider.com/hangar/delta-iv/

Figure 17: Delta IV M+ (4,2) Series of Launch Vehicles

Source: (ULA Design from http://www.ulalaunch.com/products.aspx)

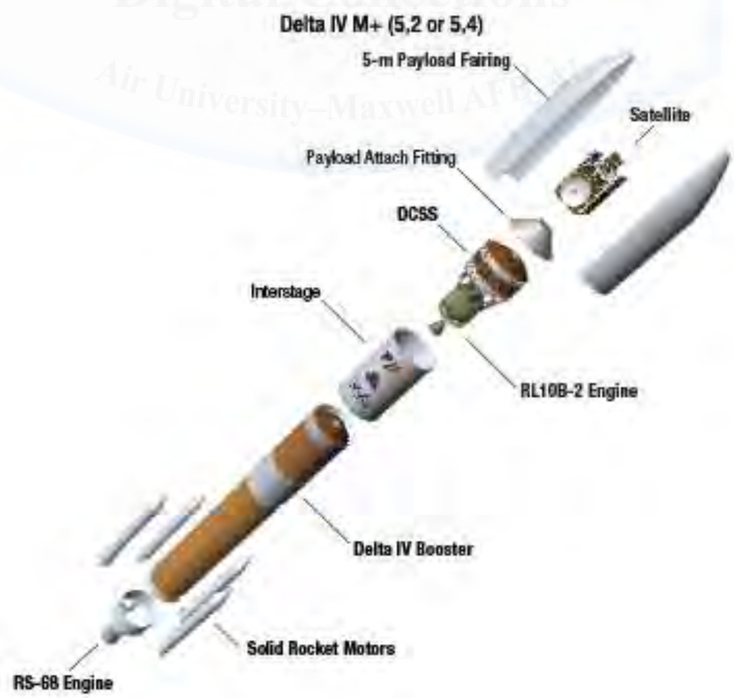

Figure 18: Delta IV M+ (5,2 or 5,4) Series of Launch Vehicles

Source: (ULA Design from http://www.ulalaunch.com/products.aspx)

Figure 19: Delta IV Heavy Series of Launch Vehicles

Source: (ULA Design from http://www.ulalaunch.com/products.aspx)

Payload Fairings

The Delta IV offers similar payload fairings to the Atlas V and Delta II.[50] The Delta IV "offers a 4-m-diameter by 11.7-m (38.5-ft)-long fairing is a composite bisector design and is used on the Delta IV M and M+(4,2). The 5-m-diameter composite fairing also is a bi-sector design and comes in two standard lengths. The 14.3 m (47 ft) fairing is used on the Delta IV M+(5,2) and M+(5,4). The 19.1 m (62.7 ft) fairing is used on the Delta IV Heavy. The 5-m metallic trisector fairing (the baseline for heritage government programs) is a modified version of the flight-proven Titan IV aluminum isogrid fairing designed and manufactured by The Boeing Company."[51]

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[50] Miller, Charles. Comments made at the Pentagon during A Rapid Global Effects Capability meeting. Washington D.C., 7 Dec 15.
[51] United Launch Alliance. http://www.ulalaunch.com/products.aspx; Spaceflight Insider. http://www.spaceflightinsider.com/hangar/delta-iv/

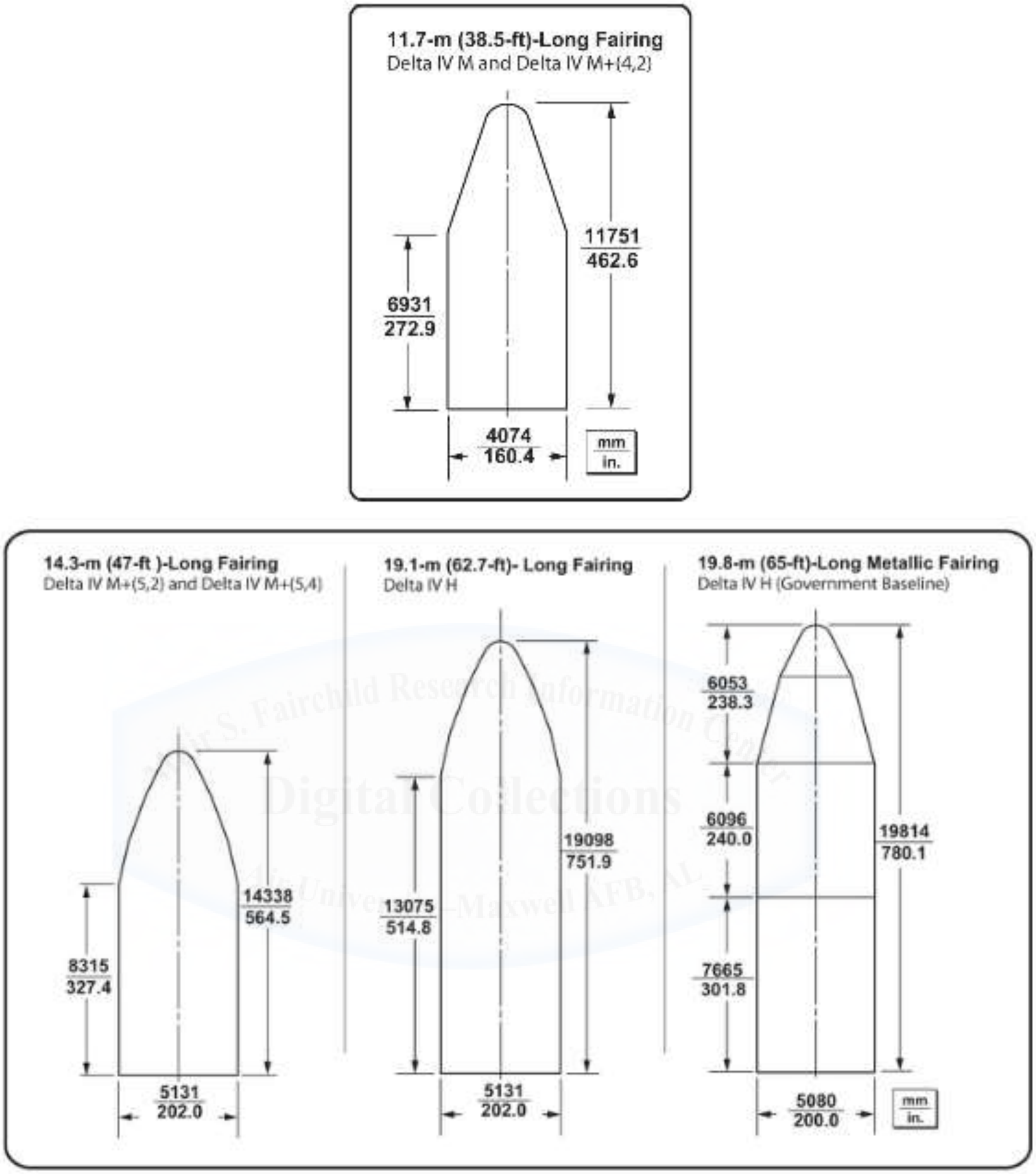

Figure 20: 11.7-m, 14-3m, 19.1-m, and 19.8 Long and Long Metallic Fairings

Source: (ULA Design from http://www.ulalaunch.com/products.aspx)

Moving forward into the future, ULA is planning its next generation in launch vehicles and calling it the Vulcan.[52] It is designed to be "more affordable, accessible, and commercialized — and innovating to develop solutions to the nation's most critical need: reliable access to space."[53] Making space more accessible by commercializing their future product line is a key strategy that ULA is pursuing. This marks a considerable shift in launch vehicle application, theory, and strategy that previous generations of launch vehicles didn't have the opportunity to pursue. ULA leadership contends, "More capabilities in space mean more capabilities here on Earth. By making it more affordable to conduct launches, Vulcan will open up brand new opportunities for the nation's use of space."[54] A key aspect of ULA future development and launch strategy rests in the flexibility of their Next Generation Launch System. "Vulcan Centaur will revolutionize spaceflight and provide affordable, reliable access to space with an American main engine," says Mark Peller, ULA's program manager for major development."[55] ULA has identified key aspects of the future of space launch, adjusting their business model in an effort to harness the emerging economic factors, such as rapid and reusable launch, that will drive down the cost to access space.[56] ULA has also identified a key missing component of American national security.[57] "The NGLS will have an American engine,

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52 Miller, Charles. Comments made at the Pentagon during A Rapid Global Effects Capability meeting. Washington D.C., 7 Dec 15.
53 Ray, Justin. *Reviewers approve early design work on new Vulcan rocket.* Spaceflight Now, 24 March 16.
54 United Launch Alliance. http://www.ulalaunch.com/products.aspx
55 Ray, Justin. *Reviewers approve early design work on new Vulcan rocket.* Spaceflight Now, 24 March 16.
56 Miller, Charles. Comments made at the Pentagon during A Rapid Global Effects Capability meeting. Washington D.C., 7 Dec 15.
57 United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.

will offer the best value and with the introduction of the Advanced Cryogenic Evolved Stage (ACES) it will have greater capability than any other rocket on the market."[58] Having an American made engine will allow the United States greater flexibility in future launch options, tying directly to other national objectives.[59] ULA outlines a two-step plan to achieve their goals with Vulcan.[60]

The first step involves achieving initial launch capabilities in 2019, in which Vulcan will have the operating capability to meet all the demands of the current Atlas V.[61] This first step will be expansive in its technical achievements. "Step one of the NGLS consists of single booster stage, the high-energy Centaur second stage and either a 4-meter or 5-meter-diameter payload fairing. Up to four solid rocket boosters (SRBs) augment the lift off power of the 4-meter configuration, while up to six SRBs can be added to the 5-meter."[62] Step two involves expanding the lift capability of the Vulcan to meet the capability of the Delta IV Heavy. In order to achieve this goal, a more powerful component will replace the Centaur second stage. This will allow the Vulcan to carry heavy payloads such as large satellites critical to national security.[63]

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[58] United Launch Alliance. http://www.ulalaunch.com/products.aspx
[59] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[60] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[61] Ray, Justin. *Reviewers approve early design work on new Vulcan rocket.* Spaceflight Now, 24 March 16.
[62] United Launch Alliance. http://www.ulalaunch.com/products.aspx
[63] Ray, Justin. *Reviewers approve early design work on new Vulcan rocket.* Spaceflight Now, 24 March 16.

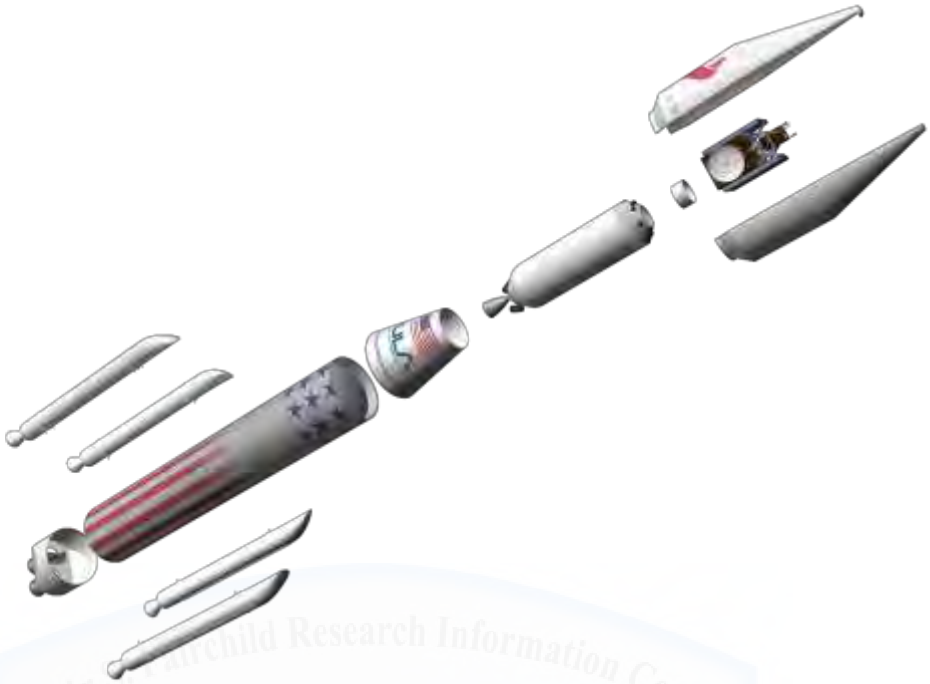

Figure 21: Vulcan 4-meter-diameter Payload Fairing Configuration

Source: (ULA Design from http://www.ulalaunch.com/products.aspx)

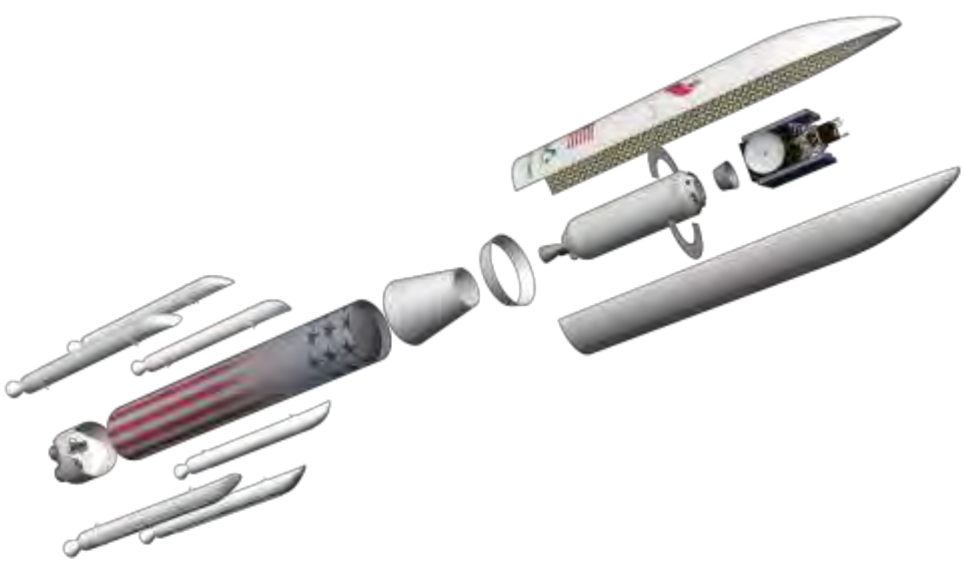

Figure 22: Vulcan 5-meter-diameter Payload Fairing Configuration

Source: (ULA Design from http://www.ulalaunch.com/products.aspx)

ULA is expanding its launch capability in an effort to be more flexible and affordable.[64] This will drive down the cost to access space on its traditional and future launch vehicles.[65] ULA realizes that this will open new opportunities in both space and on earth. ULA's efforts are bridging the domains of air and space, making them more blended as time moves forward. ULA's adjustment in their launch vehicle strategy complements other efforts in the space domain that are driving down the cost to access space.[66] Recently, other companies have begun to take non-traditional views on space, expanding on what have been traditional goals and pushing past previous limits. Their efforts complement the traditional approach in which ULA has invested.

Research and development of a wide range of technologies is advancing the idea of decreasing the cost to access space.[67] In the commercial sector, SpaceX Designs is the most noticeable entity in the field of space exploration. They are focusing their research and design on efforts to drive down the cost of accessing space through reusable platforms.[68] Ultimately, their goal is the exploration and colonization of Mars by humans. Recently, they have had quite a few important successes.

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[64] Miller, Charles. Comments made at the Pentagon during A Rapid Global Effects Capability meeting. Washington D.C., 7 Dec 15.
[65] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[66] Miller, Charles. Comments made at the Pentagon during A Rapid Global Effects Capability meeting. Washington D.C., 7 Dec 15.
[67] Miller, Charles. Comments made at the Pentagon during A Rapid Global Effects Capability meeting. Washington D.C., 7 Dec 15.
[68] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.

In 2014, SpaceX and their "commercial space program got approval to take a crew to the International Space Station – SpaceX's first such mission."[69] These missions represent a shift in U.S. government use of commercial space vehicles to travel to and/or from space. However, this shift is not without a level of accepted risk. In January of 2016, "SpaceX's…attempt to land a rocket upright on a platform in the Pacific Ocean failed in a spectacular fashion."[70] By accepting an appropriate level of risk, Space X made history when it launched a used rocket into space and then recovered it.[71] "It marked the first time in the history of spaceflight that the same rocket has been used on two separate missions to orbit."[72] It is important to distinguish acceptable levels of risk from reckless risk in the research and development of technologies associated with space exploration and a vehicles that are able to rapidly access space.[73]

Acceptable levels of risk are possible due to flexibility in the commercial research and development process.[74] Traditional acquisition, research, and development processes controlled by the U.S. government cannot compete with this process. The SpaceX use of

[69] Garcia, Ahiza. *SpaceX Gets Mission to Take NASA Crew to Space Station.* Atlanta, GA: Cable News Network, 20 Nov 2015.
[70] Wattles, Jackie and McLean, Robert. *SpaceX Rocket Explodes After Landing.* Atlanta, GA: Cable News Network, 18 Jan 16.
[71] Wattles, Jackie. *SpaceX Makes History: It Launched a Used Rocket and then Landed it in the Ocean.* Atlanta, GA: Cable News Network, 31 Mar 17.
[72] Wattles, Jackie. *SpaceX Makes History: It Launched a Used Rocket and then Landed it in the Ocean.* Atlanta, GA: Cable News Network, 31 Mar 17.
[73] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[74] United States Air Force. *Military Spaceplane, Generating and Executing Combat Spacepower; Results of the AF-NASA 120 Day Study on RLV.* Washington, D.C.: Office of the Secretary of the Air Force, 2002.

the Falcon 9 rocket is an example of this. SpaceX is able to deliver that capability at $1/10^{th}$ the cost of NASA's approach with their Falcon 9.[75]

Figure 23: CRS 9 Streak

Source: (SpaceX Picture from http://www.spacex.com/media-gallery/detail/144736/7256)

[75] Sercel, Joel. *Sub-Orbital Transport, Air Force Guardian Program Concept Initial Feasibility Analysis.* ICS Associates Inc., 2016.

Figure 24: CRS 9 Landing

Source: (SpaceX Picture from http://www.spacex.com/media-gallery/detail/144736/7246)

Blue Origin and Masten Space Systems are also leading in various technological development projects involving space exploration.[76] In a historic moment on November 24th of 2015, "Jeff Bezos' rocket ship achieved a breakthrough…by traveling 329,839 feet into outer space and then landing upright upon its return to Earth."[77] This was the first launch of a rocket in which portions of the rocket are recoverable and are in use again. Bezos' proclaimed, "Full reuse is a game changer, and we can't wait to fuel up and fly again."[78] He compares reusing rockets as airlines that fly their commercial

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[76] Miller, Charles. Comments made at the Pentagon during A Rapid Global Effects Capability meeting. Washington D.C., 7 Dec 15.

[77] Isidore, Chris, and Crane, Rachel. "Jeff Bezos' Rocket Lands Safely After Space Flight." Atlanta, GA: Cable News Network, 24 Nov 2015.

[78] Isidore, Chris, and Crane, Rachel. "Jeff Bezos' Rocket Lands Safely After Space Flight." Atlanta, GA: Cable News Network, 24 Nov 2015.

aircraft repeatedly. On April 2nd of 2016, Blue Origin made their third launch for their New Shepard rocket. "Both the rocket and the capsule, which will eventually carry paying customers, landed successfully. During this test, the capsule was carrying two microgravity experiments from the Southwest Research Institute and the University of Central Florida."[79] Ultimately, reusable rockets will have a dramatic impact on the overall cost to access space.[80]

Figure 25: Fourth Launch of same New Shepard Vehicle

Source: (Blue Origin Picture from https://www.blueorigin.com/gallery)

[79] Garcia, Ahiza. *Jeff Bezos' Space Company Blue Origin Launches and Successfully Lands Rocket.* Atlanta, GA: Cable News Network, 2 April 2016.
[80] Miller, Charles. Comments made at the Pentagon during A Rapid Global Effects Capability meeting. Washington D.C., 7 Dec 15.

Figure 26: Fourth New Shepard Landing

Source: (Blue Origin Picture from https://www.blueorigin.com/gallery)

Masten Space Systems, founded by Dave Masten, is a smaller company in comparison to SpaceX and Blue Origin. Located in the Mojave Desert, they are taking strides to redefine space launch and access. On their company website they laud, "You don't need to be a hundred miles above the Earth's surface to alter the future of space exploration, you just need to be a hundred miles north of Los Angeles. At our testing facility here in the Mojave Desert, we rapidly mature the technologies of the present into the space exploration capabilities of the future."[81] The United States government has realized their expertise in reusing rockets, awarding them contracts in the development of their XS-1 concept.

While difficult to compete with commercial design and acquisitions processes, the U.S. government is investing in technologies that will lower the cost to access space and

[81] Masten Space Systems (http://masten.aero/)

develop vehicles capable of rapid launch into space.[82] The Defense Advanced Research Projects Agency (DARPA) is exploring this field with their Experimental Spaceplane (XS-1) concept.[83]

DARPA believes that there is an increasing demand for reusable launch vehicles in the future. They base their beliefs on a growing commercial demand for flexible space launch options that both the United States and international community are demanding, as well as an increasing Department of Defense demand for flexible launch options in response to the changing nature of warfare.[84] The key in each case is the need for flexible launch options.[85]

In the commercial sector, DARPA outlines the spacecraft market, spacecraft cost, and spacecraft technology as areas influencing the need for flexible launch options. They predict that there will be a large growth in the market of spacecraft development in which the current market is not prepared to meet the demand. They also predict that emerging technologies will drive down the cost of commercial satellite costs, therefore driving the demand for low cost spacecraft to deliver low cost satellites. DARPA also sees a notable reduction in the size of spacecraft technology in the future.[86]

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[82] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[83] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[84] Sercel, Joel. *Air Force Guardian: The Offset Strategy for America's 21st Century Competitive Advantage.* ICS Associates Inc., January 2015.
[85] Ideas for this paragraph were inspired and wording used from briefing by Sponable, Jess. Comments made at Air University. Maxwell AFB, AL, 22 Feb 16.
[86] Ideas for this paragraph were inspired and wording used from briefing by Sponable, Jess. Comments made at Air University. Maxwell AFB, AL, 22 Feb 16.

In the defense sector, DARPA outlines expendable vehicle launch sites, contested space environment, and reusable 1st stage launch sites as areas influencing the need for flexible launch options. They believe that coastal launch sites are important to make an expendable system and that expanded launch flexibility reduces U.S. vulnerabilities to adversaries. They also highlight the changing dynamics of space threats and how they drive a responsive launch capability. DARPA also stresses that operations that focus on being similar to aircraft will lead to flexible basing and potential inland basing options.[87] Together, DARPA's view of the changing commercial and defense sectors has led them to design the XS-1.

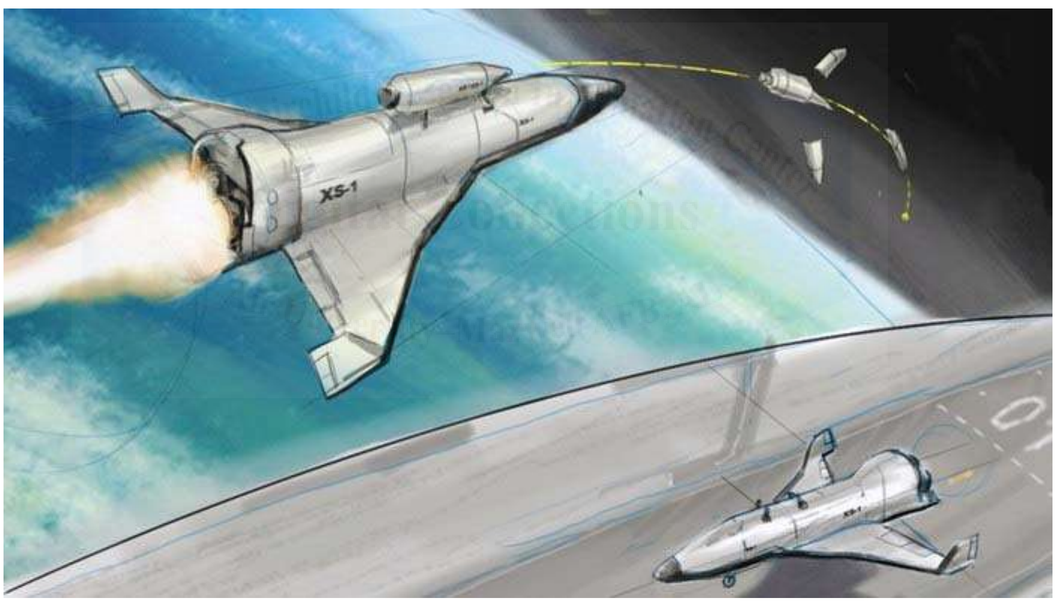

Figure 27– Artist Depiction of DARPA's XS-1

Source: Szondy, David. *DARPA's XS-1 sets goal of space launches with one-day turnaround.* Gizmag, 20 September 2013.

While DARPA's XS-1 design allows it to operate like a traditional aircraft squadron, there are some notable advantages and differences. One of XS-1's goals is to

[87] Ideas for this paragraph were inspired and wording used from briefing by Sponable, Jess. Comments made at Air University. Maxwell AFB, AL, 22 Feb 16.

provide global reach anywhere in the world within ninety minutes. It will have the ability to fly over anywhere in the world at any time. It will use unpredictable overflight patterns that make it difficult for adversaries to target, engage, and defeat. These aspects will make it more survivable in an anti-access area denial (A2AD) environment.[88] With the future in mind, the goal is to show reusability with ten flights in ten days.[89]

Mr. Barry Hellman from the Air Force Research Laboratory has been conducting research and development on how to lower the cost to access space.[90] He is particularly interested in the military application of a vehicle able to rapidly launch to access space. His concept is a launch-on-demand "space truck" based out of the continental United States.[91] Technical analysis is underway concerning the advantages and disadvantages of vertical and horizontal takeoff and landing. The design has a reusable first stage booster that returns to the launch site approximately thirty minutes after initial launch.

The "space truck" portion of the concept launches from there into low earth orbit between an altitude of 300K and 600K feet, or into space, with re-entry airspeeds of approximately Mach 25. The concept's initial design allows it to have a 20,000 pound payload, or a 6,000 pound soft payload anywhere in the world within two hours.[92] The

[88] Ideas for this paragraph were inspired and wording used from briefing by Sponable, Jess. Comments made at Air University. Maxwell AFB, AL, 22 Feb 16.
[89] Szondy, David. *DARPA's XS-1 sets goal of space launches with one-day turnaround.* Gizmag, 20 September 2013.
[90] Hellman, Barry and St. Germain, Dr. Brad. *A Rapid Global Effects Capability Concept Briefing.* Maxwell AFB, AL, 2015.
[91] Hellman, Barry and St. Germain, Dr. Brad. *A Rapid Global Effects Capability Concept Briefing.* Maxwell AFB, AL, 2015.
[92] Hellman, Barry and St. Germain, Dr. Brad. *A Rapid Global Effects Capability Concept Briefing.* Maxwell AFB, AL, 2015.

"space truck" deploys a payload to a target area and then recovers to the launch site or another designated site.[93]

The deployable payload releases approximately 2,500 – 4,000 miles prior to the target area. The payload reaches the ground approximately 20 minutes after release. This creates a three to four minute communications blackout period.[94] The anticipated G-loading is six on ascent and nine for capsule re-entry. Mr. Hellman bases his concept on technologies that are currently in development in both the military and commercial sectors.[95]

[93] Hellman, Barry and St. Germain, Dr. Brad. *A Rapid Global Effects Capability Concept Briefing.* Maxwell AFB, AL, 2015.
[94] Hellman, Barry and St. Germain, Dr. Brad. *A Rapid Global Effects Capability Concept Briefing.* Maxwell AFB, AL, 2015.
[95] Hellman, Barry and St. Germain, Dr. Brad. *A Rapid Global Effects Capability Concept Briefing.* Maxwell AFB, AL, 2015.

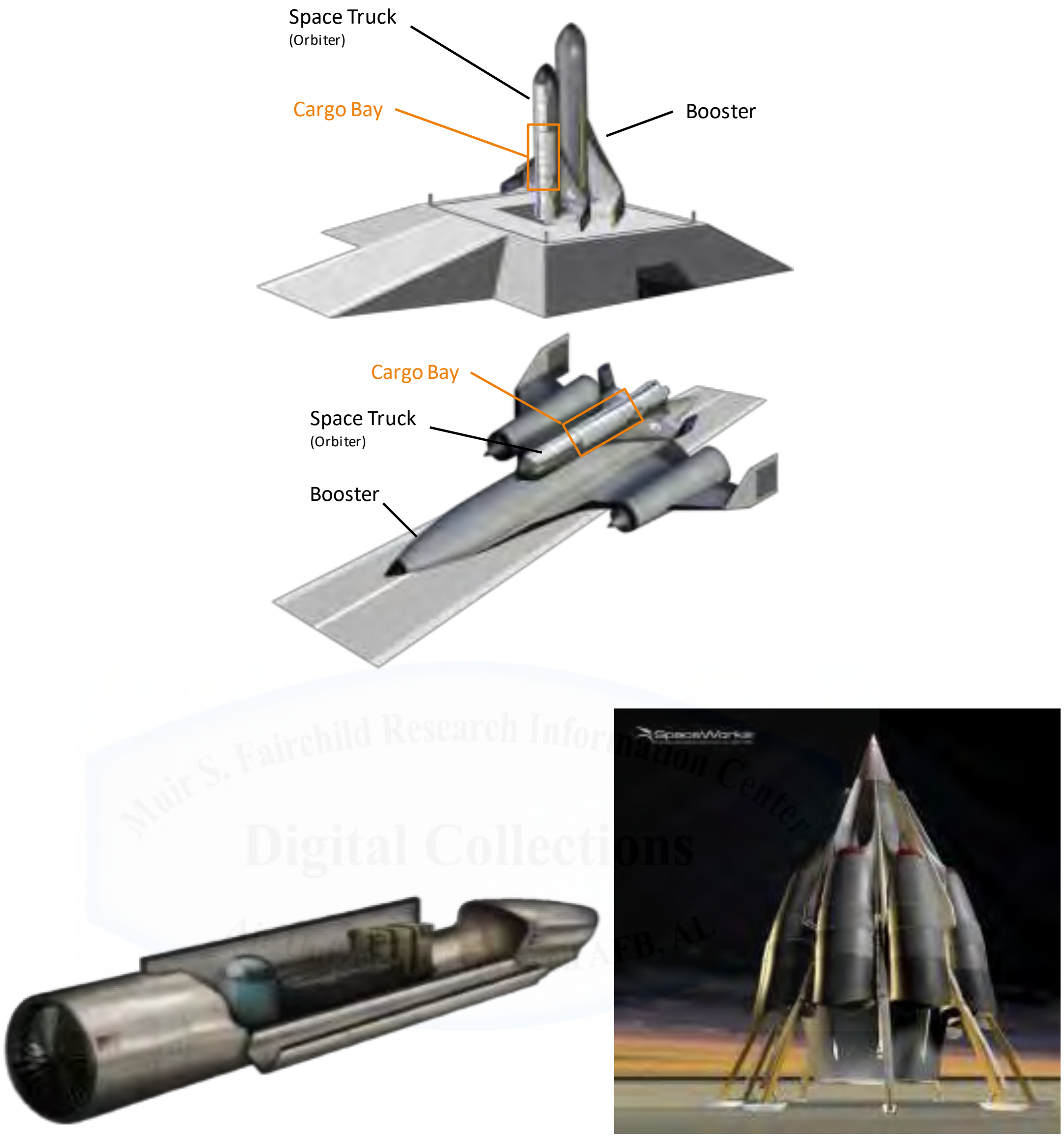

Figure 28 – Artist depictions of Rapid Global Effects Capability platforms

Source: Hellman, Barry and Bradford, John. *A Rapid Global Effects Capability Concept Briefing for Major Commands.* Wright-Patterson AFB, OH, 2015.

Figure 29 – Artist depiction of Expendable Entry Capsule and its deployment

Source: Hellman, Barry and Bradford, John. *A Rapid Global Effects Capability Concept Briefing for Major Commands.* Wright-Patterson AFB, OH, 2015.

Reusable, low-cost launch capabilities will make lowering the cost to access space a reality for the United States.[96] Currently, access to space cost around $10,000/kg. Low cost access to space is considered by many to be a factor 10 times lower than that.[97] This number is relative,[98] however, to the economic incentives that asteroid mining[99] and associated activities in space can bring to mankind.[100] This type of cost "disruptions

[96] United States Air Force. *Military Spaceplane, Generating and Executing Combat Spacepower; Results of the AF-NASA 120 Day Study on RLV.* Washington, D.C.: Office of the Secretary of the Air Force, 2002.
[97] Ideas from discussions with Sercel, Joel. *Sub-Orbital Transport, Air Force Guardian Program Concept Initial Feasibility Analysis.* ICS Associates Inc., 2016.
[98] Harrison, Todd, Hunter, Andrew, Johnson, Kaitlyn, and Roberts, Thomas. *Implications of Ultra-Low Cost Access to Space.* Washington, D.C.: Center for Strategic and International Studies, Feb 2017.
[99] Colby, Elbridge. *The Implications of the Commercialization of Space and ULCATS for a U.S. Limited War Defense and Deterrence Strategy for Space.* Washington, D.C.: Center for a New American Security, Nov 16.
[100] Hellman, Barry. *Conceptual Cost Estimates for Air Guardian Vehicle Concepts.* Wright-Patterson AFB, OH, 5 Nov 15.

would cause the global space market to change."[101] ULA, SpaceX, Blue Origin, and Masten are just a few of the commercial companies pursuing technologies to lower the cost to access space. DARPA and the United States government are partnering with commercial industries to make this a reality. As the cost is lowered, space will have greater applications to humankind, presenting new opportunities and challenges. There are a number of emerging technologies that will complement the effort to decrease the cost to access space while highlighting potential future uses of space vehicles.[102]

[101] Harrison, Todd, Hunter, Andrew, Johnson, Kaitlyn, and Roberts, Thomas. *Implications of Ultra-Low Cost Access to Space.* Washington, D.C.: Center for Strategic and International Studies, (Feb 2017) 11.
[102] United States Air Force. *Military Spaceplane, Generating and Executing Combat Spacepower; Results of the AF-NASA 120 Day Study on RLV.* Washington, D.C.: Office of the Secretary of the Air Force, 2002.

Chapter 5

Emerging Technologies

A wide variety of emerging technologies will both lower the cost to access space and/or enable the United States Air Force to achieve greater operational agility and accomplish its core missions in the future. In November of 2015, Deputy Secretary of Defense Work outlined his five points of interest in emerging technologies. They include Learning Systems, Human-machine Collaboration, Human-machine Combat Teaming, Assisted Human Operations, and Networked-enabled, Cyber-hardened Autonomous Weapons.[1] These five points of interest will shape investment and policy for the Department of Defense moving forward.[2] Each of these categories have applicability in lowering the cost to access space and achieving the United States Air Force's future core missions.[3] In the transition between President Obama and President Trump's administration, Deputy Secretary Work has continued in his role as the Deputy Secretary of Defense, ensuring that these points of interest in emerging technology remain a focal point in the Department of Defense. There is recent research that complements these points of interest while having application to where commercial industry is taking space applications and investment.[4] Historical theory and strategy is closely linked to emerging technologies that will influence their shifts when applied to space theory and strategy.

[1] Work, Deputy Secretary of Defense, Bob. Speech given at The Reagan National Defense Forum. California, 7 Nov 15.
[2] Simpson, Ray. Comments made at Wright-Patterson AFB, OH working group with Air University. Wright-Patterson AFB, OH, 22 Sept 15.
[3] Sercel, Joel. *Air Force Guardian: The Offset Strategy for America's 21st Century Competitive Advantage.* ICS Associates Inc., January 2015.
[4] Sercel, Joel. *Air Force Guardian: The Offset Strategy for America's 21st Century Competitive Advantage.* ICS Associates Inc., January 2015.

Significant research is underway on autonomy and swarming technology.[5] The Air Force Research Laboratory is researching autonomy to counter land mines, sea mines, missile defense, and anti-access area denial environments through space power application. Such a study is fundamentally linked to lowering the cost to access space. A dominant question is, "How does the United States deal with data overload?" Is there a way to couple autonomy and artificial intelligence with human decision makers to reduce tasking overload? Reid Porter works on Data Analytics and Autonomy at Los Alamos National Laboratory and is answering this very question. Many argue that merging the fields of air and space will help with the autonomy, swarming, and human decision making complex. Lowering the cost to access space will allow for the further development of XS-1 type space vehicles, in turn offering a solution for delivering a host of emerging technologies such as autonomous swarms[6] while utilizing speed and maneuver to create an advantage in warfare.[7] Using space-based vehicles to delivery drone technology or cruise missile-type packages around the world will heavily impact the United States Air Force's ability to accomplish its core missions.

In 2015 Air University conducted a wargame to note the impact that an autonomous swarm capability would have on an integrated air defense system. The technology, called CLEAVER, is a cruise missile launched from an airlift asset. CLEAVER is a light-weight system; a C-17 can carry a substantial number. CLEAVER

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[5] Simpson, Ray. Comments made at Wright-Patterson AFB, OH working group with Air University. Wright-Patterson AFB, OH, 22 Sept 15.

[6] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.

[7] United States Air Force. *Military Spaceplane, Generating and Executing Combat Spacepower; Results of the AF-NASA 120 Day Study on RLV.* Washington, D.C.: Office of the Secretary of the Air Force, 2002.

has standoff capability outside of A2AD environments, such as the one that China is creating in the South China Sea. However, the wargame displayed that CLEAVER's range is limited because of the delivery requirement from a traditional airlift asset.[8] The CLEAVER system also has the ability to form an integrated network with other CLEAVER assets that are airborne. CLEAVER assets have the ability to perform strike, command and control, and intelligence, surveillance, and reconnaissance missions. Additionally, CLEAVER would have the ability to carry directed energy capabilities.[9] By decreasing the cost to access space, space vehicles like the XS-1 will have the capability to deliver CLEAVER assets around the world within hours.[10] With the research that civilian industry is doing, as well as their operational tests of using reusable rockets to reenter and land, employment of CLEAVER through traditional payload fairings is currently possible.

Perhaps the most high-profile directed energy technology is a system called CHAMP (Counter-electronics High Power Microwave Advanced Missile Project.) CHAMP is a joint concept technology demonstration led by the Air Force Research Laboratory, Directed Energy Directorate at Kirtland Air Force Base and Boeing Corporation to develop an air-launched directed-energy weapon capable of incapacitating or damaging electronic systems.[11] This directed energy technology, combined with an

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[8] James, John. Comments made at the Air Force Research Laboratory. Wright-Patterson AFB, OH, 22 Sept 15.
[9] Ideas and information for this paragraph were inspired from wording used from LeMay Center Wargaming Directorate personnel in 2015 and 2016.
[10] Akhadov, Elshan. Interview conducted at Los Alamos National Laboratory. Los Alamos, NM, 14 Oct 15.
[11] Torres, Robert. *CHAMP*. Interview by Maj. Gabe Arrington, October 2015. Sandia National Laboratory, Kirtland AFB, NM.

appropriate delivery platform, offers operational agility to the armed forces.[12] Boeing contends that flight tests "in the Utah desert may change future warfare after the missile successfully defeated electronic targets with little to no collateral damage."[13] Both the United States Air Force and Boeing laud the benefit of having a non-kinetic alternative to traditional strike options.[14] During testing, CHAMP successfully "navigated a pre-programmed flight plan and emitted bursts of high-powered energy, effectively knocking out the target's data and electronic subsystems. CHAMP allows for selective high-frequency radio wave strikes against numerous targets during a single mission."[15] Keith Coleman, CHAMP program manager for Boeing, stresses that "this technology marks a new era in modern-day warfare."[16] He believes that "in the near future, this technology may be used to render an enemy's electronic and data systems useless even before the first troops or aircraft arrive."[17] As the CHAMP technology matures, the Department of Defense will look to delivery platforms. While traditional assets such as the B-2 or C-17 offer potential choices, the need for quicker delivery options as the nature of warfare continues to evolve will become more of a priority.[18] As this occurs, delivery options

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[12] Simpson, Ray. Comments made at Wright-Patterson AFB, OH working group with Air University. Wright-Patterson AFB, OH, 22 Sept 15.
[13] Boeing Corporation. http://www.boeing.com/features/2012/10/bds-champ-10-22-12.page
[14] Akhadov, Elshan. Interview conducted at Los Alamos National Laboratory. Los Alamos, NM, 14 Oct 15.
[15] Boeing Corporation. http://www.boeing.com/features/2012/10/bds-champ-10-22-12.page
[16] Boeing Corporation. http://www.boeing.com/features/2012/10/bds-champ-10-22-12.page
[17] Boeing Corporation. http://www.boeing.com/features/2012/10/bds-champ-10-22-12.page
[18] Akhadov, Elshan. Interview conducted at Los Alamos National Laboratory. Los Alamos, NM, 14 Oct 15.

from space vehicles will become an attractive option as the cost to access space decreases. Also, a CHAMP capability within orbit has the potential to bring a new dimension to space warfare, complementing the capability or eliminating the need for ground-based anti-satellite (ASAT) weapons.[19]

Figure 30 – CHAMP Missile

Source: (Picture courtesy Air Force Research Laboratory, Directed Energy Directorate at Kirtland Air Force)

[19] Torres, Robert. *CHAMP*. Interview by Maj. Gabe Arrington, October 2015. Sandia National Laboratory, Kirtland AFB, NM.

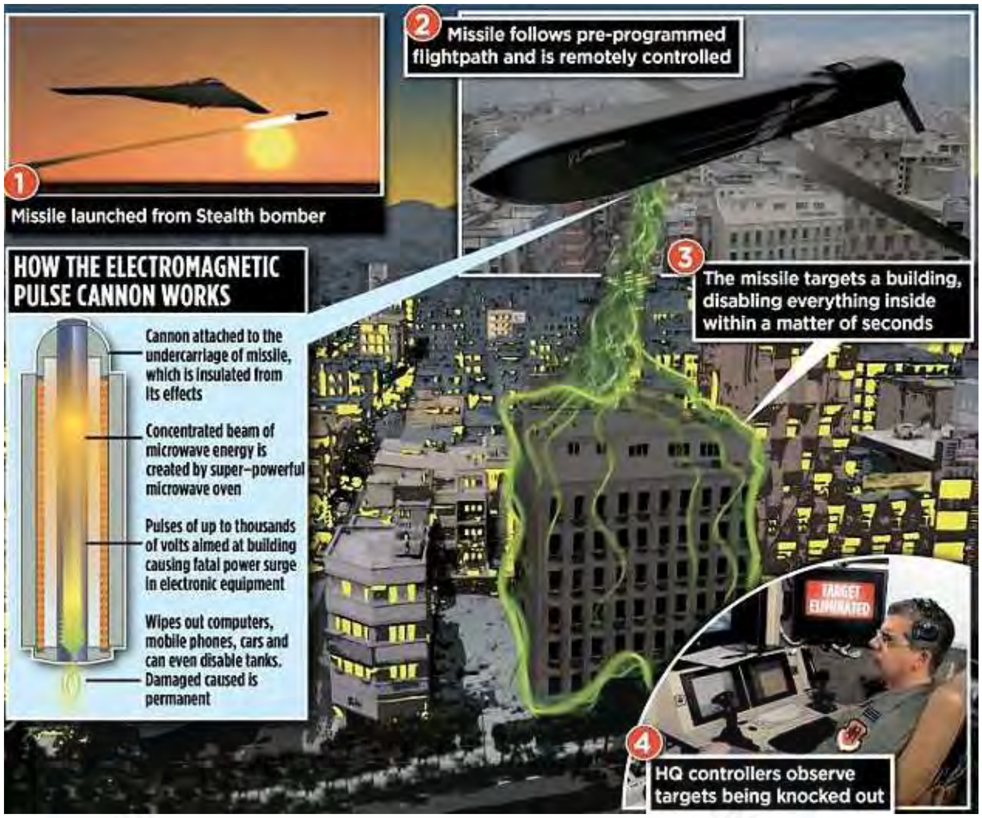

Figure 31 – CHAMP Mission Scenario

Source: (Graphic courtesy of DailyMail.com)

The combination of the lowering cost to access space, emerging technologies, and the changing nature of warfare has the potential to link Deputy Secretary of Defense Work's five points of interest together.[20] Execution through the space domain offers the ability to manipulate the aspect of time in comparison to traditional delivery platforms.[21] This aspect of warfare will promote Human-machine collaboration, Human-machine Combat Teaming, Assisted Human Operations, and Network-enabled, Cyber-hardened

[20] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[21] Oliver, Kelly. Comments made at the Air Force Research Laboratory. Wright-Patterson AFB, OH, 22 Sept 15.

autonomous weapons.[22] Delivery options through space enabled by decreasing costs have the ability to deliver a swarm of autonomous drones, strike assets, ISR capability, not to mention rapidly reconstituting satellites to orbit.[23] Technological improvements in 3D-printing, cubesats, and new space suits are also examples of how the cost to access space is decreasing while pairing with Deputy Secretary Work's main points of interest.[24]

Behrokh Khoshnevis, an engineering professor from the University of South Carolina, is redefining how humans look at space exploration and its possibilities. "In 2004, Khoshnevis unveiled a revolutionary 3D-printing method dubbed Contour Crafting (CC), which made it possible to print a 2,500-square-foot building in less than a day on Earth."[25] In theory, this technology makes it possible to 3D-print critical infrastructure to provide shelter, work space, or create earth-like conditions in space. In 2016 Khoshnevis took his creation one step further when he "took first prize in the NASA In-Situ Materials Challenge, for Selective Separation Sintering -- a 3D-printing process that makes use of powder-like materials found on Mars and works in zero-gravity conditions."[26] Thus, he has created the ability to use the materials found in space, on places like Mars and the Moon, to 3D-print infrastructure, tools, and many other things critical to sustain life. In doing so, Khoshnevis is lowering the cost to access space. Previously, these materials

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[22] Simpson, Ray. Comments made at Wright-Patterson AFB, OH working group with Air University. Wright-Patterson AFB, OH, 22 Sept 15.
[23] United States Air Force. *Military Spaceplane, Generating and Executing Combat Spacepower; Results of the AF-NASA 120 Day Study on RLV.* Washington, D.C.: Office of the Secretary of the Air Force, 2002.
[24] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[25] Springer, Kate. *Meet the man working with NASA to 3D print a colony on Mars.* Atlanta, GA: Cable News Network, 22 Feb 17.
[26] Springer, Kate. *Meet the man working with NASA to 3D print a colony on Mars.* Atlanta, GA: Cable News Network, 22 Feb 17.

would need to launch on large space vehicles in order to build things like the International Space Station. 3D-printing offers a solution to greatly reduce the cost to access space.[27] CubeSats offer another solution.

Historically, satellites have been large acquisition projects requiring significant time and capitol to produce.[28] They tend to be large in both weight and dimension, requiring the larger payload fairings and launch vehicles to deliver them to space.[29] CubeSats are changing this historical paradigm.[30] In 1999, California Polytechnic State University, San Luis Obispo and Stanford University created CubeSat. Their goal is to facilitate "frequent and affordable access to space with launch opportunities available on most launch vehicles."[31] The critical aspect of CubeSats is that they are significantly smaller and lighter than historically built satellites.[32] According to the National Aeronautics and Space Administration (NASA), "CubeSats are a class of research spacecraft called nanosatellites. CubeSats are built to standard dimensions (Units or "U") of 10x10x11. They can be 1U, 2U, 3U, or 6U in size, and typically weigh less than 1.33 kg (3 lbs.) per U. NASA's CubeSats are deployed from a Poly-Picosatellite Orbital Deployer, or P-POD."[33]

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27 United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
28 Gelfand, Boris. Interview conducted at Los Alamos National Laboratory. Los Alamos, NM, 14 Oct 15.
29 Gelfand, Boris. Interview conducted at Los Alamos National Laboratory. Los Alamos, NM, 14 Oct 15.
30 Smith, Michael. Comments made at the Center for Strategic and Budgetary Assessments Space Workshop. Washington D.C., 9 and 10 Nov 15.
31 CubeSat. http://www.cubesat.org
32 Smith, Michael. Comments made at the Center for Strategic and Budgetary Assessments Space Workshop. Washington D.C., 9 and 10 Nov 15.
33 National Aeronautics and Space Administration. https://www.nasa.gov/mission_pages/cubesats/overview

NASA believes so strongly in the future of this technology that it has created a CubeSat Launch Initiative (CSLI). The CSLI is an effort to provide access to space for CubeSats "developed by the NASA Centers and programs, educational institutions and non-profit organizations giving CubeSat developers access to a low-cost pathway to conduct research in the areas of science, exploration, technology development, education or operations."[34] The payloads that are developed are available to 'rideshare' space on planned missions with extra payload room.[35] The satellites weigh approximately three pounds and are about four inches long.[36] In order to qualify for CSLI, "CubeSat investigations should be consistent with NASA's Strategic Plan and the Education Strategic Coordination Framework. The research should address aspects of science, exploration, technology development, education or operations."[37] NASA's CSLI program has been very successful to date.

CSLI efforts have studied a wide range of topics important to the United States government. "In the past, selected science investigation missions have studied Earth's atmosphere, near earth objects, space weather and biological sciences. Technology demonstration missions have included in-space propulsion, space power, radiation testing and solar sails."[38] By allowing access to space through this type of paradigm shift,

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34 National Aeronautics and Space Administration. https://www.nasa.gov/mission_pages/cubesats/overview

35 Colby, Elbridge. *The Implications of the Commercialization of Space and ULCATS for a U.S. Limited War Defense and Deterrence Strategy for Space.* Washington, D.C.: Center for a New American Security, Nov 16.

36 National Aeronautics and Space Administration. https://www.nasa.gov/mission_pages/cubesats/overview

37 National Aeronautics and Space Administration. https://www.nasa.gov/mission_pages/cubesats/overview

38 National Aeronautics and Space Administration. https://www.nasa.gov/mission_pages/cubesats/overview

NASA is encouraging further development in CubeSats and other related technologies while promoting innovative partnerships across multiple industries and government.[39] As a result, “NASA has selected 152 CubeSat missions from 85 unique organizations representing 38 states and the District of Columbia.”[40] NASA’s efforts have been critical in the advancement of CubeSat technology.

CubeSat technology, interest, and proliferation has spread quickly around the world since its early inception.[41] The following graphic depicts the level of interest from companies and governments around the world who are currently developing CubeSat technology.[42] Clearly, this type of technology and others like it are proliferating rapidly.

Figure 32 – CubeSat Proliferation Depiction

[39] United States Air Force. *Military Spaceplane, Generating and Executing Combat Spacepower; Results of the AF-NASA 120 Day Study on RLV*. Washington, D.C.: Office of the Secretary of the Air Force, 2002.
[40] National Aeronautics and Space Administration. https://www.nasa.gov/mission_pages/cubesats/overview
[41] Smith, Michael. Comments made at the Center for Strategic and Budgetary Assessments Space Workshop. Washington D.C., 9 and 10 Nov 15.
[42] CubeSat. http://www.cubesat.org

Source: (Graphic courtesy of CubeSat)

There are additional advancements in space technology that are lowering the cost to access space. For instance, Boeing has developed a new spacesuit for astronauts to use on missions. Astronaut Eric Boe commented that the new suit is “a lot lighter, more form-fitting and it's simpler, which is always a good thing,”[43] and “Complicated systems have more ways they can break, so simple is better on something like this."[44] The key component of the new suit is the fact that it’s significantly lighter than previous spacesuits. “The new, blue suit weighs only 20 pounds, that's 10 pounds less than the launch-and-entry suits astronauts wear today. Other features include: touchscreen-sensitive gloves; visor and helmet incorporated in the suit and more flexibility in the elbows and knees to allow more freedom of movement.”[45] While ten pounds may not seem like much, that’s a 33% reduction in weight for astronauts. This allows for greater use of energy on critical mission aspects such as scientific experiments. Overall, this also reduces the cost to access space. If the cost to access space is roughly $10,000/kg, the cost saving is significant.[46] By decreasing the weight ten pounds, the reduction in kilograms is roughly 4.53592. That equates to a cost saving of over $45,000 for every new spacesuit that is launched into space.

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[43] Jackson, Amanda. *Boeing unveils new, blue spacesuits.* Atlanta, GA: Cable News Network, 25 Jan 17.
[44] Jackson, Amanda. *Boeing unveils new, blue spacesuits.* Atlanta, GA: Cable News Network, 25 Jan 17.
[45] Jackson, Amanda. *Boeing unveils new, blue spacesuits.* Atlanta, GA: Cable News Network, 25 Jan 17.
[46] Sercel, Joel. *Air Force Guardian: The Offset Strategy for America’s 21st Century Competitive Advantage.* ICS Associates Inc., January 2015.

Figure 33 – Boeings New Spacesuit

Source: (Graphic courtesy of Boeing)

Emerging technologies are driving down the cost to access space while complementing Deputy Secretary Work's five points of interest in emerging technologies:[47] Learning Systems, Human-machine Collaboration, Human-machine Combat Teaming, Assisted Human Operations, and Networked-enabled, Cyber-hardened Autonomous Weapons.[48] CLEAVER, CHAMP, CubeSats, and new spacesuits are just a sampling of the emerging technologies that will decrease the cost to access space while entering new areas of warfare.[49] The pairings of these technologies with autonomy,

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[47] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[48] Work, Deputy Secretary of Defense, Bob. Speech given at The Reagan National Defense Forum. California, 7 Nov 15.
[49] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.

swarming, and directed energy technology allows for the armed forces to achieve operational agility and better achieve its future missions.[50]

[50] United States Air Force. *Military Spaceplane, Generating and Executing Combat Spacepower; Results of the AF-NASA 120 Day Study on RLV*. Washington, D.C.: Office of the Secretary of the Air Force, 2002.

Chapter 6

United States Government Policy

On October 11, 2016, President Barack Obama made space exploration a premier goal of the United States. The President said, “We have set a clear goal vital to the next chapter of America's story in space: sending humans to Mars by the 2030s and returning them safely to Earth, with the ultimate ambition to one day remain there for an extended time. Getting to Mars will require continued cooperation between government and private innovators, and we're already well on our way.”[1] The President is outlining a policy that coincides with a shift in investment strategies relating to the defense of the United States.

President Trump’s administration is also taking steps to expand the United States’ space exploration efforts. On February 28, 2017, President Trump, in his address to Congress, said, “American footprints on distant worlds are not too big a dream.”[2] During his Presidential campaign, President Trump also spoke about his thoughts on space exploration and the future of NASA. On October 25, 2016, President Trump said, “"I will free NASA from the restriction of serving primarily as a logistics agency for low-Earth orbit activity—big deal. Instead, we will refocus its mission on space exploration. Under a Trump Administration, Florida and America will lead the way into the stars."[3] He also said, “A cornerstone of my policy is we will substantially expand public private partnerships to maximize the amount of investment and funding that is available for space exploration and development. This means launching and operating major space

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[1] Obama, President Barack. *America Will Take Giant Leap To Mars.* Atlanta, GA: Cable News Network, 11 October 2016.
[2] Trump, President Donald. Remarks in his address to Congress. 28 February, 2017.
[3] Trump, President Donald. Remarks made in Sanford, Florida. 25 October, 2016.

assets, right here that employ thousands and spur innovation and fuel economic growth."[4] As a result, there are a growing number of leaders throughout government, industry, and defense advocating for increased partnership.[5]

The political environment is calling for a change in investment strategies as they relate to technology.[6] Senator John McCain has highlighted the need to allow the military services to have more ownership over their acquisition processes. In granting this, the armed forces will be better able to enforce acquisition reform and advance accountability. He also stressed the importance of the 2015 National Defense Authorization Act and the need to incentivize commercial investment in a speech to the U.S. Chamber of Commerce.[7] Senator McCain boldly said:

> We need reform on this scale because our Nation is at a key inflection point. For the past decade, America's adversaries have invested heavily in rapidly improving their militaries to counter our unique advantages. At the same time, the speed of globalization and commercialization means that advanced disruptive technologies are now—and increasingly will be—available to less sophisticated militaries, terrorist groups, and other non-state actors.
>
> In the face of these trends, our Defense Department has grown larger but less capable, more complex but less innovative, more proficient at defeating low-tech adversaries but more vulnerable to high-tech ones. And the self-inflicted wounds of drastic defense cuts have made all of this worse.[8]

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[4] Trump, President Donald. Remarks made in Sanford, Florida. 25 October, 2017
[5] Pasztor, Andy. *Trump Space Policy Options Emphasize Role of Private Enterprise.* New York, NY: Wall Street Journal, 5 Feb 17.
[6] Smith, Michael. Comments made at the Center for Strategic and Budgetary Assessments Space Workshop. Washington D.C., 9 and 10 Nov 15.
[7] McCain, John. *Remarks On Defense Acquisition Reform at the U.S. Chamber of Commerce.* Washington, D.C., 2015.
[8] McCain, John. *Remarks On Defense Acquisition Reform at the U.S. Chamber of Commerce.* Washington, D.C., 2015.

In these remarks, Senator McCain is analyzing emerging technologies both domestically and abroad to make conclusions on the potential military capabilities of near-peer competitors to the United States. He combines historical theory and strategy with these emerging technologies, making the conclusion that the United States must adjust its national and military strategies to take advantage of technical changes. He continues:

> As a result, we are now flirting with disaster: our military technological advantage is eroding – and eroding fast – precisely as the rules-based international order, which has been anchored by U.S. hard power for seven decades, is being seriously stressed around the world, and with it, the foundation of our security and prosperity.
>
> Changing course and maintaining our military technological advantage is about much more than a larger defense budget or a better fighter or submarine. These things are important, but to give our military the capabilities it needs to defend the nation, the Department of Defense must be able to access innovation in areas such as cyber, robotics, data analytics, miniaturization, and autonomy – innovation that is increasingly likely not to come from Washington or the defense establishment.[9]

In this section of his remarks, Senator McCain agrees with Deputy Secretary of Defense Work's five points of interest in emerging technologies. While there is overlap in developmental areas, the two aren't identical. Senator McCain describes the sectors of technological development that he sees as critical to defend the nation, while Deputy Secretary Work narrows those sectors into more specific capabilities that he's interested in. Senator McCain also says:

[9] McCain, John. *Remarks On Defense Acquisition Reform at the U.S. Chamber of Commerce.* Washington, D.C., 2015.

In other words, the Pentagon confronts an emerging innovation gap. Commercial R&D in the United States overtook government R&D in 1980, and now represents 75 percent of the national total. The top four U.S. defense contractors combined spend only 27 percent of what Google does annually on R&D. The problem grows worse beyond our borders. Global R&D is now more than twice that of the United States. And Chinese R&D levels are projected to surpass the United States in 2022.

Even when the Defense Department is innovating, it is moving too slowly. Innovation is measured in 18-month cycles in the commercial market. The Defense Department has acquisition cycles that can last 18 years. This is due to a defense acquisition system that has been broken for decades. It takes too long and costs too much—and that's if it actually produces something. According to one estimate, the Defense Department spent $46 billion between 2001 and 2011 on at least a dozen programs that never became operational.

This broken acquisition system, with its complex regulation and stifling bureaucracy, leads many commercial firms to choose not to do business with the Defense Department, or to limit their engagement in ways that prevent the Department from accessing the critical technologies that these companies have to offer. If we are going to maintain our military technological advantage, we simply cannot afford a defense acquisition system with regulations so byzantine that compliance becomes a competitive advantage. Our military should be doing business with companies where the best minds work in the laboratory, not the legal department.

That's why a major focus of the NDAA is improving access to non-traditional and commercial contactors. The NDAA incentivizes commercial innovation by removing barriers to new entrants into the defense market. By adopting commercial buying practices for the Defense Department, the bill makes it easier for non-traditional firms to do business with the Pentagon. And crucially, we ensure that businesses are not forced to cede intellectual property developed at their expense to the government.[10]

[10] McCain, John. *Remarks On Defense Acquisition Reform at the U.S. Chamber of Commerce.* Washington, D.C., 2015.

The last section of remarks by Senator McCain calls for a change in the research, development, and acquisition processes. His thoughts, combined with foundation laid by President Obama and the vision of President Trump concerning more commercial influence in the overall process, are changing the way the government, military, and industry pursue developing technologies and capabilities. The House Committee on Armed Services has also identified this as an issue of importance to the national security of the United States.[11] This shift in developmental culture will enable a change in acquisitions models, covered in the next chapter, that will lower the cost to access space.[12]

Other elected leaders are also stressing the importance to defense investment and partnership. Congressman Jim Bridenstine, of the House Armed Services Committee and House Science, Space and Technology Committee, spoke of the importance of defense partnerships with space industry leaders in his opening remarks for a panel at The Heritage Foundation on May 11, 2016.[13] The panel, consisting of the leading experts on space policy, largely agreed upon the importance of driving down the cost to access space and the advantages that would follow for the United States. One such advantage highlighted is Ultra Low Cost Access to Space (ULCATS), which will enable a space vehicle capable of delivering strategic effects anywhere in the world within two hours.

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[11] United States House of Representatives Committee on Armed Forces. *Assessing Progress and Identifying Future Opportunities in Defense Reform.* Washington, D.C.: U.S. House of Representatives, 4 Apr 17.

[12] United States House of Representatives Committee on Armed Forces. *Assessing Progress and Identifying Future Opportunities in Defense Reform.* Washington, D.C.: U.S. House of Representatives, 4 Apr 17.

[13] Heritage Foundation Panel. Comments by The Honorable Jim Bridenstine, House Armed Services Committee and House Science, Space and Technology Commitee. Washington D.C., 11 May 2016.

Advances in technology are providing the U.S. military with opportunities to address challenges in ways not previously available. Regarding general space policy, The Heritage Foundation says, "The U.S. has many vital space interests at stake including: protecting U.S. and allied territories against weapons based in space or that transit space, projecting U.S. military power around the world, intelligence gathering, and a variety of civilian applications."[14] Each of these interests supports lowering the cost to access space, expanding space vehicle capability, and enhancing operational agility in and through space.

In Congressional testimony, the Vice-Chairman of the Joint Chiefs of Staff identified Russia as the leading threat to the existence of the United States.[15] Many strategists believe that the only options the military could offer to the President of the United States during Russian aggression in Crimea were either nuclear attack or acquiescence.[16] These viewpoints are an example of the shifting nature of warfare; one in which agility is needed to address a plethora of varied threats.[17] Additionally, public Chinese statements regarding their intent to use celestial bodies for commercial interests and documented space exploration efforts lead strategists to believe that the space domain will become more contested in the future.[18] Finally, on November 28, 2016, the

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[14] Heritage Foundation. http://www.heritage.org/space-policy

[15] Selva, General Paul J. *Trends in Military Technology and the Future Force.* Comments made at the Brookings Institution. Washington D.C., 21 Jan 16.

[16] Smith, Michael. Comments made at the Center for Strategic and Budgetary Assessments Space Workshop. Washington D.C., 9 and 10 Nov 15.

[17] United States House of Representatives Committee on Armed Forces. *Assessing Progress and Identifying Future Opportunities in Defense Reform.* Washington, D.C.: U.S. House of Representatives, 4 Apr 17.

[18] Russian Times. Complete success: Shenzhou 11 returns Chinese duo to Earth after longest space mission. Russian Times, 18 Nov 16.

Commander of U.S. Strategic Command highlighted the need to expand the U.S. defense efforts in space against Chinese and Russian strategic investments in comments to CNN.[19] In regards to the competition that is moving forward in space, General Hyten said, "It's a competition that I wish wasn't occurring, but it is. And if we're threatened in space, we have the right of self-defense, and we'll make sure we can execute that right."[20] The shifting nature of warfare is calling for agility in the armed forces, particularly in space.[21]

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[19] Hyten, Gen. John. Comments made to Cable New Network. Atlanta, GA: Cable News Network, 28 Nov 16.
[20] Hyten, Gen. John. Comments made to Cable New Network. Atlanta, GA: Cable News Network, 28 Nov 16.
[21] Colby, Elbridge. *The Implications of the Commercialization of Space and ULCATS for a U.S. Limited War Defense and Deterrence Strategy for Space.* Washington, D.C.: Center for a New American Security, Nov 16.

Chapter 7

United States Government Innovation and Acquisitions Implications

Given the direction that government policy is trending and the emergence of technologies that lower the cost of space access, there are a number or acquisition implications to consider. The manner in which the United States government chooses to acquire technologies and potential platforms has a profound impact on the direction of warfare and domains in which warfare takes place.[1] Acquisition considerations will determine just how low the cost to access space will be driven down, subsequently impacting how great of an impact space will have on the future set of United States Air Force core missions.[2] The basis of modern doctrinal development and innovation are a combination of Dr. Barry R. Posen and Dr. Stephen P. Rosen's opinions. Their considerations are apparent in the United States Department of Defense (DoD) acquisition strategy today,[3] which is presently shifting through the development of organizations like the Defense Innovation Unit Experimental (DIUX).[4] Academia, industry, and think tanks also have ideas on how to optimize United States government acquisitions with regard to lowering the cost to access space.

Dr. Stephen P. Rosen is a Harvard College professor and the Beton Michael Kaneb Professor of National Security and Military Affairs. Rosen suggests that

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[1] Sercel, Joel. *Air Force Guardian: The Offset Strategy for America's 21st Century Competitive Advantage.* ICS Associates Inc., January 2015.
[2] United States Air Force. *Military Spaceplane, Generating and Executing Combat Spacepower; Results of the AF-NASA 120 Day Study on RLV.* Washington, D.C.: Office of the Secretary of the Air Force, 2002.
[3] Heritage Foundation. Interview with Ms. Michaela Dodge. Washington D.C., 2 March 2016.
[4] United States Air Force. *New IDAG Structure.* Washington, D.C.: Office of the Secretary of the Air Force, 15 Jan 16.

innovative doctrinal and acquisitions advancements occur through either a professionalist or institutionalist approach. He argues that professionals within military organizations are responsible and most capable of solving the most pressing challenges, and acquiring the correct platforms to do so. This is an argument that Senator John McCain of Arizona would agree with, in his viewpoints expressed on the National Defense Authorization Act already mentioned in Chapter 6. Rosen breaks his view into three classes of military innovation and acquisition: peacetime, wartime, and technological. Given the nature of modern conflict, these three classes are often blurred and potentially overlap over various time periods.[5]

There is significant debate about how to properly innovate and acquire new technologies in the military.[6] Rosen believes "pessimism about bureaucratic innovation has led to despair and to the hope that it might be possible to ignore "the bureaucracy" and to substitute a small group of talented individuals for the bureaucracy when change is needed."[7] This is something that is apparent in the changing nature of modern United States Department of Defense innovation and acquisition efforts.[8] Most notably, the DoD has established multiple DIUX locations to streamline innovation and acquisition, which we will discuss later in this chapter. While peacetime innovation tends to take the

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5 Heritage Foundation. Interview with Mr. John Venable. Washington D.C., 2 March 2016.
6 Sercel, Joel. *Air Force Guardian: The Offset Strategy for America's 21st Century Competitive Advantage.* ICS Associates Inc., January 2015.
7 Rosen, Stephen P. *Winning the Next War: Innovation in the Modern Military*. Ithaca, NY: Cornell University Press, (1991), 2.
8 United States Air Force. *New IDAG Structure.* Washington, D.C.: Office of the Secretary of the Air Force, 15 Jan 16.

longest amount of time and can be the most burdensome,[9] Rosen believes that it is the most effective. This form of innovation "occurs when respected senior military officers formulate a strategy for innovation, which has both intellectual and organizational components."[10] Peacetime innovation and acquisition requires extensive debate, and is often difficult because intelligence is incomplete and potential adversaries vary based on their interests.[11] This leads to an analysis of risk in development and acquisition strategies.[12] Peacetime environments in history show that "military planners were driven to consider the need for innovation by broad structural changes in the security environment in which their organizations would have to fight for the foreseeable future, not by specific capabilities or intentions of potential adversaries."[13] Rosen also notes that due to the nature of peacetime innovation and acquisition, new organizations are often required in order to develop and utilize emerging technologies. The modern example of this is the DoD's creating of DIUX.[14] A historical example of this is the United States Air Force's development of the Inter-Continental Ballistic Missile, in which it created a new organization in Southern California to research, develop, and organize the emerging

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[9] Heritage Foundation. Interview with Mr. Dean Cheng. Washington D.C., 2 March 2016.

[10] Rosen, Stephen P. *Winning the Next War: Innovation in the Modern Military*. Ithaca, NY: Cornell University Press, (1991), 21.

[11] Heritage Foundation. Interview with Mr. Dean Cheng. Washington D.C., 2 March 2016.

[12] Sercel, Joel. *Air Force Guardian: The Offset Strategy for America's 21st Century Competitive Advantage.* ICS Associates Inc., January 2015.

[13] Rosen, Stephen P. *Winning the Next War: Innovation in the Modern Military*. Ithaca, NY: Cornell University Press, (1991), 75.

[14] United States Air Force. *New IDAG Structure.* Washington, D.C.: Office of the Secretary of the Air Force, 15 Jan 16.

technologies required to field the eventual capability.[15] The key in peacetime innovation and acquisition is having the correct military professionals in key positions.[16] These select professionals must have the intellect to bridge the gap between emerging technologies, current capabilities, and the future nature of warfare that few are able to envision.[17] Rosen relates this aspect of innovation and acquisition to the officer promotion system. He says, "Peacetime innovations are possible, but the process is long. When changes in the structure of promotions that favor the innovation can be made, the officer corps changes over time, but the process is only as fast as the rate at which young officers rise to the top."[18] An effective foundation of peacetime innovation and acquisition helps to bridge the gap between peacetime and wartime challenges.[19]

Innovation in wartime tends to be more sporadic due to the challenges of conflict. There is an increased sense of urgency and the risk level becomes heightened.[20] In light of this environment, Rosen contends "there is an advantage to tight central command, so that the organization can be rapidly reorganized once the need for innovation is perceived."[21] The key to success in this type of environment rests in creating an

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[15] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[16] Gelfand, Boris. Interview conducted at Los Alamos National Laboratory. Los Alamos, NM, 14 Oct 15.
[17] Sercel, Joel. *Air Force Guardian: The Offset Strategy for America's 21st Century Competitive Advantage.* ICS Associates Inc., January 2015. (Comments made on Acquisition Strategy and Team)
[18] Rosen, Stephen P. *Winning the Next War: Innovation in the Modern Military*. Ithaca, NY: Cornell University Press, (1991), 105.
[19] United States Air Force. *New IDAG Structure.* Washington, D.C.: Office of the Secretary of the Air Force, 15 Jan 16.
[20] Gelfand, Boris. Interview conducted at Los Alamos National Laboratory. Los Alamos, NM, 14 Oct 15.
[21] Rosen, Stephen P. *Winning the Next War: Innovation in the Modern Military*. Ithaca, NY: Cornell University Press, (1991), 110.

opportunity to fail.[22] Being able to fail quickly and smartly in any innovative and acquisitions environment is critical to the overall success of the organization.[23] To this end Rosen says, "If an appropriate strategic measure of effectiveness is in place, information can be collected that is relevant to that measure, so that organizational learning leading to reform can take place. When military innovation is required in wartime, however, it is because an inappropriate strategic goal is being pursued, or because the relationship between military operations and that goal has been misunderstood."[24] Essentially, in wartime professionals are required to innovate and acquire capabilities because prior strategic estimates were wrong or insufficient.[25] Peacetime innovation tries to minimize this disconnect, hoping to create an environment in which required wartime innovation and acquisition is at a minimum.[26] There are ample examples in which wartime innovation has been required. For instance, "The U.S. Army Air Forces strategic bombing forces developed two new military capacities in World War II: the ability to provide tighter escorts to bombers on mission and the ability to analyze the enemy to determine the targets the destruction of which would present him with the greatest difficulty in waging war."[27] Throughout World War II, military

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[22] Heritage Foundation. Interview with Ms. Michaela Dodge. Washington D.C., 2 March 2016.
[23] Sercel, Joel. *Air Force Guardian: The Offset Strategy for America's 21st Century Competitive Advantage.* ICS Associates Inc., January 2015.
[24] Rosen, Stephen P. *Winning the Next War: Innovation in the Modern Military*. Ithaca, NY: Cornell University Press, (1991), 35.
[25] Heritage Foundation. Interview with Ms. Michaela Dodge. Washington D.C., 2 March 2016.
[26] United States Air Force. *New IDAG Structure.* Washington, D.C.: Office of the Secretary of the Air Force, 15 Jan 16.
[27] Rosen, Stephen P. *Winning the Next War: Innovation in the Modern Military*. Ithaca, NY: Cornell University Press, (1991), 149.

innovation led to acquisition of new capabilities and the associated changes in tactics and doctrine that followed.[28] Technological innovation and acquisition was a key part of this process.

During technological innovation and acquisition, Rosen argues that military professionals use enemy doctrine, technological developments, and overall intelligence reports to pursue technologies and platforms of their own that will provide for a decisive advantage in warfare. Considering these aspects of innovation and acquisition, Rosen believes "peacetime military innovation appears to have been more successful in dealing with changes in the character of warfare than wartime innovation."[29] Ultimately, in an environment as uncertain as modern-day warfare, flexibility and innovation are the keys to future success.[30] Dr. Barry Posen offers different viewpoints on the sources of policy, doctrine, innovation, and acquisition. By examining his thoughts and comparing them to Rosen, we are better able to understand the historical basis of innovation and acquisition in the United States government and military. Through this understanding, we are able to see how current reforms are shifting innovation and acquisition strategy and lowering the cost to space access.

Dr. Barry Posen is the Ford International Professor of Political Science at the Massachusetts Institute of Technology (MIT), the Director of the MIT Security Studies Program, and serves on the Executive Committee of Seminar XXI, a senior level

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[28] Heritage Foundation. Interview with Mr. John Venable. Washington D.C., 2 March 2016.
[29] Rosen, Stephen P. *Winning the Next War: Innovation in the Modern Military*. Ithaca, NY: Cornell University Press, (1991), 180.
[30] Sercel, Joel. *Air Force Guardian: The Offset Strategy for America's 21st Century Competitive Advantage.* ICS Associates Inc., January 2015.

education platform for general officers in the military. These are important details considering the United States military's long history of innovation and acquisition through the professionals at MIT. Also, the United States military uses Seminar XXI to educate its senior leaders on strategic issues and methods of thought. Thus, Dr. Posen's opinions on policy directly influence how the United States government and military innovate and acquire emerging technologies and platforms.[31]

Posen argues that military policies are determined by either organizational theory or by balance of power theory. He believes that military doctrine plays a key role in grand strategy by setting "priorities among various military forces and prescribing how those forces should be structured and employed to achieve the ends in view."[32] In this regard, Posen calls upon the military to identify the strategic shifts in emerging technologies and respond accordingly in order to achieve national objectives.[33] He says, "States and military organizations are responsible for interpreting new military technologies and responding to geographic constraints and opportunities."[34] There is a critical link between innovation, acquisition, and military doctrine that combine to have a special relationship with grand strategy.[35] Posen notes, "Innovation in military doctrine and its converse, stagnation, can affect national security in two ways. First, they can

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[31] United States Air Force. *New IDAG Structure.* Washington, D.C.: Office of the Secretary of the Air Force, 15 Jan 16.
[32] Posen, Barry R. *The Sources of Military Doctrine: France, Britain, and Germany between the World Wars*. Ithaca NY: Cornell University Press, (1984), 7.
[33] Heritage Foundation. Interview with Mr. John Venable. Washington D.C., 2 March 2016.
[34] Posen, Barry R. *The Sources of Military Doctrine: France, Britain, and Germany between the World Wars*. Ithaca NY: Cornell University Press, (1984), 39.
[35] Sercel, Joel. *Air Force Guardian: The Offset Strategy for America's 21st Century Competitive Advantage.* ICS Associates Inc., January 2015.

affect integration; second, they can affect the likelihood of victory or defeat."[36] Thus, military professionals are called upon to envision various threats and recommend the best strategic course of innovation and acquisition to counter these threats and achieve national objectives.[37] Posen outlines three situations in which military professionals have the best chance to promote innovative advancements to the point of acquisition.

In a broad sense, organizational innovation and acquisition is neither probable nor likely.[38] Historically, a catalyst is needed to spur an organization into accepting innovation and acquisition that will change the nature of their business, or in the case of the Department of Defense, warfare.[39] This is due to the supposed gap in civil-military relations in which the priorities of government officials and the innovative ideas of military professionals tend not to overlap.[40] Posen argues that there are three instances in which innovation and acquisition occur. "First, organizations innovate when they fail. Second, organizations innovate when they are pressured from without. Third, organizations innovate because they wish to expand."[41] In these instances, a strategic shift forces innovation and acquisition of new ideas, doctrines, and capabilities.[42] Each

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[36] Posen, Barry R. *The Sources of Military Doctrine: France, Britain, and Germany between the World Wars*. Ithaca NY: Cornell University Press, (1984), 29.
[37] United States Air Force. *New IDAG Structure.* Washington, D.C.: Office of the Secretary of the Air Force, 15 Jan 16.
[38] Heritage Foundation. Interview with Mr. Dean Cheng. Washington D.C., 2 March 2016.
[39] Sercel, Joel. *Air Force Guardian: The Offset Strategy for America's 21st Century Competitive Advantage.* ICS Associates Inc., January 2015.
[40] Gelfand, Boris. Interview conducted at Los Alamos National Laboratory. Los Alamos, NM, 14 Oct 15.
[41] Posen, Barry R. *The Sources of Military Doctrine: France, Britain, and Germany between the World Wars*. Ithaca NY: Cornell University Press, (1984), 47.
[42] Gelfand, Boris. Interview conducted at Los Alamos National Laboratory. Los Alamos, NM, 14 Oct 15.

of these situations is apparent throughout the history of the United States Air Force. For instance, the United States Air Force created a peacetime training environment to simulate a wartime environment called Red Flag. It chose innovate in this manner, acquiring vast training areas in Nevada, due to tactical losses in the Vietnam War. This innovation allowed pilots to create different scenarios that portray combat through the acquisition of various emerging technologies that simulate adversary platforms. Similarly, the United States Air Force developed Strategic Air Command and its associated weapons platforms in response to a bipolar world and the threat of nuclear war. The development of the United States Air Force's ICBM capabilities represents an instance in which the service chose to expand as well. These organizational innovations and acquisitions are closely linked to balance of power theory.

States will "balance in two general ways: coalition formation and internal mobilization."[43] Innovation and acquisition fall into the category of internal mobilization. Due to the difficult nature of determining relative power between multiple states throughout the world, "military organizations will generally prefer offensive doctrines because they reduce uncertainty."[44] States take a realist view on the world and prefer offensive doctrines because they feel more in control of events. Offensive doctrines, innovations, and acquisition projects increase the military's size, capability, and overall autonomy.[45] Defensive mindsets and acquisitions, on the other hand, tend to

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[43] Posen, Barry R. *The Sources of Military Doctrine: France, Britain, and Germany between the World Wars*. Ithaca NY: Cornell University Press, (1984), 61.
[44] Posen, Barry R. *The Sources of Military Doctrine: France, Britain, and Germany between the World Wars*. Ithaca NY: Cornell University Press, (1984), 49.
[45] Heritage Foundation. Interview with Ms. Michaela Dodge. Washington D.C., 2 March 2016.

favor states that prefer relaying on coalitions in order to provide for the collective defense. A historical example of a defensive doctrine is France in 1940 prior to World War II. The United States is seen as an offensive minded country due to its history in warfare and the manner in which it rewards capitalism to many nations in the world.[46] The relationship between the United States' military and civilian industry is allowing for important changes to occur in innovation and acquisition efforts.[47] The United States Air Force is combining the ideas of both Rosen and Posen in order to respond to a shifting strategic environment.[48]

The blurring between peacetime and wartime environments as well as a shift in organizational and balance of power theories has led to a shift in how the world views strategic environments.[49] The United States has arguably been at war since 1991 during Operation Desert Storm. Prior to that, some would argue that the United States was at war with the Soviet Union since the end of World War II. The spectrum of conflict has changed dramatically, changing how the world defines peace and war.[50] Moving forward, states will continue to face the challenge of how to define these two terms and more than likely fail to find themselves in an absolute state of either.[51] This strategic

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[46] Heritage Foundation. Interview with Ms. Michaela Dodge. Washington D.C., 2 March 2016.
[47] Sercel, Joel. *Air Force Guardian: The Offset Strategy for America's 21st Century Competitive Advantage.* ICS Associates Inc., January 2015.
[48] United States Air Force. *New IDAG Structure.* Washington, D.C.: Office of the Secretary of the Air Force, 15 Jan 16.
[49] United States Air Force. *New IDAG Structure.* Washington, D.C.: Office of the Secretary of the Air Force, 15 Jan 16.
[50] Heritage Foundation. Interview with Mr. Dean Cheng. Washington D.C., 2 March 2016.
[51] Secure World Foundation Panel. Comments by Mr. Kenneth Hodgkins, Director, Office of Space and Advanced Technology, U.S. Department of State. Washington D.C., 5 May 2016.

shift has also changed how the world views the balance of power.[52] With new domains of warfare in space and cyber continuing to grow, what the world has previously viewed as the most dominant instruments of power are also shifting.[53] As states utilize instruments of power other than their military to create advantages against the United States, organizations within the Department of Defense and civilian industry will be required to adjust their organizational innovation and acquisition strategies to compensate for this shift in the strategic environment.[54]

The result of a shifting strategic environment has been an increase in collaboration between the government (DoD), civilian industry, and academia.[55] In a large sense civilian industry is now leading the research and development of emerging technologies, a shift from the historical lead that the government and DoD had, particularly in defense related fields.[56] This is evident in the examples previously discussed involving companies like ULA, SpaceX, and Blue Origin. Likewise, academia is a leading proponent in new doctrines, operating procedures, and capability procurement suggestions. Quite simply, academia has more time to critically analyze issues of national security than the armed forces. Due to the "peculiar character of

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[52] Secure World Foundation Panel. Comments by Mr. Kenneth Hodgkins, Director, Office of Space and Advanced Technology, U.S. Department of State. Washington D.C., 5 May 2016.

[53] Heritage Foundation. Interview with Mr. Dean Cheng. Washington D.C., 2 March 2016.

[54] Sercel, Joel. *Air Force Guardian: The Offset Strategy for America's 21st Century Competitive Advantage.* ICS Associates Inc., January 2015.

[55] United States Air Force. *Military Spaceplane, Generating and Executing Combat Spacepower; Results of the AF-NASA 120 Day Study on RLV.* Washington, D.C.: Office of the Secretary of the Air Force, 2002.

[56] Sercel, Joel. *Air Force Guardian: The Offset Strategy for America's 21st Century Competitive Advantage.* ICS Associates Inc., January 2015.

military organizations in peacetime they are simply unlikely to innovate at all if left to themselves: military innovation must be the result of civilian intervention."[57] This thought is due to a lack of urgency or situation that forces innovation. The strategic shift has led to an operational focus by the military establishment in order to achieve national security objectives.[58] Rightly, the DoD's partnership with industry and academia to address the United States' toughest challenges is proving fruitful.[59] Also, the DoD is expanding the role of its educational institutions, like the United States Air Force's Air University, allowing them to partner with industry and other academic partners to address strategic challenges.[60] One of the DoD's answers to this is the creating of Defense Innovation Unit Experimental (DIUx).

In its mission statement, DIUx says it "serves as a bridge between those in the U.S. military executing on some of our nation's toughest security challenges and companies operating at the cutting edge of technology."[61] The first DIUx was created in 2015 in Silicon Valley, California. Each unit is designed to be flexible in order to rapidly identify and acquire emerging technologies applicable to defense of the United States for the DoD. Their mission statement goes on to say that DIUx "continuously iterate on how best to identify, contract, and prototype novel innovations through sources traditionally not available to the Department of Defense, with the ultimate goal of accelerating

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[57] Rosen, Stephen P. *Winning the Next War: Innovation in the Modern Military*. Ithaca, NY: Cornell University Press, (1991), 9.
[58] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[59] Heritage Foundation. Interview with Mr. Dean Cheng. Washington D.C., 2 March 2016.
[60] Disbrow, Lisa. Meeting conducted at the Pentagon. Washington, D.C., 7 Dec 15.
[61] Department of Defense. https://www.diux.mil/#mission

technology into the hands of the men and women in uniform."[62] The DoD made Silicon Valley the first location of DIUx to make a statement about its commitment to changing how the DoD innovates and acquires technology. Silicon Valley is the first of a few DIUx locations that have proven to be successful in changing innovation and acquisition.[63]

On 26 July, 2016, Secretary of Defense Ash Carter was in Boston, Massachusetts, to announce the opening of the second DIUx location there. In May of 2016, he announced "DIUx 2.0, to accelerate DIUx success in building bridges to entrepreneurs and innovators. The Boston location…would provide important access to a core of innovative companies, universities and other private institutions in the region, while enhancing its outreach to companies located throughout the country."[64] Secretary Carter also outlined changes to the structural and management strategy for DIUx. Those changes included the DIUx teams reporting directly to the Deputy Secretary. The Secretary also highlighted the public-private partnership that he is emphasizing with his selection of "Chief Science Officer Bernadette Johnson, the former chief technology officer at MIT Lincoln Laboratories; and Boston military lead Col. Mike McGinley, a lawyer specializing in cybersecurity issues who serves as an Air Force Reserve cyberwarrior."[65] In doing so, the DoD is capitalizing on its long-term successful

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62 Department of Defense. https://www.diux.mil/#mission
63 Oti, Enrique. *SECAF Visit Summary to DiUX.* Silicon Valley, CA: DiUX, 11 Jan 16.
64 Department of Defense. *News Release: Secretary Carter Opens Second DIUx Location in Boston, Updates DoD Outreach to Tech Community*. Washington, D.C.: Department of Defense Press Operations, 26 June 2016.
65 Department of Defense. *News Release: Secretary Carter Opens Second DIUx Location in Boston, Updates DoD Outreach to Tech Community*. Washington, D.C.: Department of Defense Press Operations, 26 June 2016.

relationship with MIT's Lincoln Laboratories while also hiring professionals from the local community. The Secretary is quite literally creating an economic environment in which the innovative success of the community also directly benefits the DoD. He has created a completely new organizational structure to capitalize on individual cities' strengths. He is not stopping there, either. In the same speech, "The Secretary also announced that DIUx is exploring ways to bring together leading minds in the military and DoD who work on biodefense and biological technology together with world-class academic researchers, biotech companies, and entrepreneurs such as Broad Institute Founding Director Eric Lander."[66] Secretary Carter also expanded the strategic engagement role of DIUx in his speech in Boston as well. DIUx shifted its organizational structure in order to promote and capitalize on rapid innovation. In doing so, it restructured to be "organized into three teams: a Venture Team, which will identify emerging commercial technologies and explore their potential impact on the battlefield; a Foundry Team, which will identify technologies that aren't yet fully developed or require significant adaptation for military applications; and an Engagement Team, which will introduce innovators to military problems and the military to entrepreneurs who can help find solutions."[67]

In September of 2016, Secretary Carter traveled to Silicon Valley in an effort to establish a lasting partnership with the technological companies that have headquarters

[66] Department of Defense. *News Release: Secretary Carter Opens Second DIUx Location in Boston, Updates DoD Outreach to Tech Community*. Washington, D.C.: Department of Defense Press Operations, 26 June 2016.
[67] Department of Defense. *News Release: Secretary Carter Opens Second DIUx Location in Boston, Updates DoD Outreach to Tech Community*. Washington, D.C.: Department of Defense Press Operations, 26 June 2016.

there. In his address to the tech giants of Silicon Valley he said, "The Defense Department needs to be flexible and more "user-friendly" to attract the very best in the highly competitive tech community."[68] Deputy Secretary Carter's visit was designed to build a stronger bridge between the DoD and tech industries. He also highlighted the shift in innovation and development throughout the last forty years, outlining how the DoD will evolve its strategies to be on the cutting edge of innovation, development, and acquisition. In referencing previous generations, Deputy Secretary Carter said, "It was a different world…The bridges between the government and the tech community were bigger and stronger…Back then, the tech community was largely based in the United States and depended on the government for funding."[69] He contrasted his views on the historical model of innovation and acquisition with what he sees as the strategic environment today and how he believes the United States should change. Deputy Secretary Carter emphasized, "Today, it's global, it's vibrant, and much of it takes place independent of the government…That's good, but it means that I have an extra responsibility to try to build bridges to it and keep bridges to it and keep that connection strong."[70] Deputy Secretary Carter has identified the strategic shift in warfare and culture. He is taking the necessary steps to maximize a whole of government approach to innovation and acquisition.

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[68] Fernando, Lisa. *Carter Visits Silicon Valley to 'Build Bridges' With Tech Community.* Washington, D.C.: DoD News, Defense Media Activity, 13 September, 2016.
[69] Fernando, Lisa. *Carter Visits Silicon Valley to 'Build Bridges' With Tech Community.* Washington, D.C.: DoD News, Defense Media Activity, 13 September, 2016.
[70] Fernando, Lisa. *Carter Visits Silicon Valley to 'Build Bridges' With Tech Community.* Washington, D.C.: DoD News, Defense Media Activity, 13 September, 2016.

The day after his trip to Silicon Valley to stress the importance of building a bridge between defense acquisition and tech professionals, Deputy Secretary Carter was in Austin, Texas with another big announcement. While in Austin, he announced the creation of an additional DIUx office there. The DoD's vision for the Austin office, "Like the existing DIUx offices in Silicon Valley and Boston, the team in Austin will link the department with America's leading innovators, so they can help address our national security challenges and ensure America's warfighters remain on the cutting edge of technology."[71] In addressing the technology community in Austin, Deputy Secretary Carter stressed, "I created DIUx last year because one of my core goals as secretary of defense has been to build, and in some cases rebuild, the bridges between our national security endeavor at the Pentagon and America's wonderfully innovative and open technology community…Austin's commitment to innovation, access to talent and academia, as well as the department's longstanding ties to Texas make this an ideal next location for DIUx."[72] The format of how DIUx will be staffed and located is telling as well. The team there will have offices in Austin's technology hub, the Capitol Factory. Christy Abizaid, a longtime defense professional with experience in national security affairs, leads it. Most striking, is the team's composition in DIUx, Austin. It will "primarily be filled by local reservists and National Guard members already working within Austin's tech community. Abizaid will report to DIUx Managing Partner Raj

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[71] Department of Defense. *News Release: Secretary Carter Announces DIUx Presence in Austin, Texas*. Washington, D.C.: Department of Defense Press Operations, 14 September 2016.

[72] Department of Defense. *News Release: Secretary Carter Announces DIUx Presence in Austin, Texas*. Washington, D.C.: Department of Defense Press Operations, 14 September 2016.

Shah."[73] Thus, it will be composed of local innovative experts, and the military component will report to a managing partner outside of traditional DoD acquisition circles. This is a significant step in establishing a public-private partnership that is agile enough to respond to shifting strategic challenges.[74]

DIUx is addressing some of the DoD's most pressing concerns in fields like autonomy, artificial intelligence, and machine learning. These areas consist of three out of the five areas in which Deputy Secretary Carter is has focused DoD efforts in relation to emerging technologies. He notes, "DIUx has made significant progress in finding commercial solutions to some of these problems through its new contracting mechanism, the commercial solutions opening or CSO."[75] In effect, the DoD has redefined the acquisitions process through DIUx and CSO. "The CSO allows tech firms to bring ideas to DOD in the same way they would to other buyers of commercial technology, streamlining paperwork requirements and allowing the department to provide funding in less than 60 days after first contact with a firm and within 30 days after receiving a formal proposal."[76] This shift in innovation efforts and acquisitions strategy has had striking results. Deputy Secretary Carter also outlined the impact that DIUx has had thus far. "To date, DIUx has signed five agreements for $3.5M, our first within just 31 days

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[73] Department of Defense. *News Release: Secretary Carter Announces DIUx Presence in Austin, Texas*. Washington, D.C.: Department of Defense Press Operations, 14 September 2016.
[74] Heritage Foundation. Interview with Mr. John Venable. Washington D.C., 2 March 2016.
[75] Department of Defense. *News Release: Secretary Carter Announces DIUx Presence in Austin, Texas*. Washington, D.C.: Department of Defense Press Operations, 14 September 2016
[76] Department of Defense. *News Release: Secretary Carter Opens Second DIUx Location in Boston, Updates DoD Outreach to Tech Community*. Washington, D.C.: Department of Defense Press Operations, 26 June 2016.

from initial company contact to award. Another 22 projects are in the pipeline, totaling an additional $65M of forthcoming investment. Because DIUx operates on a co-investment model in which it pools funds with the military end-users it works with, DIUx's $17 million of R&D expenditure is augmented by $51 million of additional funding by others within the department. For each $1 DIUx invests in innovative technology, other parts of the department are investing nearly $3."[77]

An additional example of how the DoD is shifting its organizational innovation and acquisition strategy in response to a shift in the strategic environment is the creation of the MD5 National Security Technology Accelerator. The effort is "a public-private partnership between the Department of Defense (DoD), New York University (NYU) and a large network of top U.S. research universities"[78] designed to streamline innovation, research, development, and acquisition efforts. Through the creation of MD5, the DoD is building a "network of innovators and entrepreneurs equipped with the incentives, expertise, know-how, and resources required to successfully develop, commercialize and apply DoD technology."[79] This type of partnership has led to some of mankind's greatest technological innovations, such as the Global Positioning System (GPS) that is critical to daily activities around the world. The Director of MD5, Adam Jay Harrison, highlighted

[77] Department of Defense. *News Release: Secretary Carter Announces DIUx Presence in Austin, Texas*. Washington, D.C.: Department of Defense Press Operations, 14 September 2016.
[78] Department of Defense. *News Release: MD5 – A New Department of Defense National Security Technology Accelerator – Officially Launches with Disaster Relief Hackathon in New York City*. Washington, D.C.: Department of Defense Press Operations, 14 October 2016.
[79] Department of Defense. *News Release: MD5 – A New Department of Defense National Security Technology Accelerator – Officially Launches with Disaster Relief Hackathon in New York City*. Washington, D.C.: Department of Defense Press Operations, 14 October 2016.

its importance by saying, “While the Department of Defense maintains an unparalleled commitment to inventing the future, we do not have a monopoly on innovation or sufficient resources to apply and scale all of the great technology that we produce. Our mission is to develop the people and human-centered networks necessary to compete and win in the rapidly changing technology and national security environments.”[80] General Paul Selva, the Vice-Chairman of the Joint Chiefs of Staff, himself a longtime supporter of innovation in technological fields, stressed the importance of efforts like MD5. General Selva said, “Through programs like MD5, the defense department will continue to cultivate innovation and creative problem solving as a core leadership competence and expand opportunities to collaborate with our partners in academia and industry to solve our biggest national security challenges."[81]

Many are beginning to take notice of how the DoD has shifted its innovation and acquisition strategies and are beginning to apply the same kind of thinking to other endeavors. For instance, The Atlantic Council published *Atlantic Council Strategy Paper No.5, Toward a New National Security Space Strategy: Time for a Strategic Rebalancing.* In his foreword, former Vice Chairman of the Joint Chiefs of Staff, General James E. Cartwright says, “This is the right time to reconsider our actions in space, as a new presidential administration takes over in January 2017. As technologies

[80] Department of Defense. *News Release: MD5 – A New Department of Defense National Security Technology Accelerator – Officially Launches with Disaster Relief Hackathon in New York City*. Washington, D.C.: Department of Defense Press Operations, 14 October 2016.
[81] Department of Defense. *News Release: MD5 – A New Department of Defense National Security Technology Accelerator – Officially Launches with Disaster Relief Hackathon in New York City*. Washington, D.C.: Department of Defense Press Operations, 14 October 2016.

further improve the world's ability to access and operate in space, the new administration will need to rethink how the United States wants to act alongside its fellow nations.[82] In addition, the exciting developments in the private sector will only continue to shape and evolve the space domain to the point that consistent strategic decisions will be required."[83] General Cartwright is looking towards the future and identifying key aspects of the shifting strategic environment. He highlights the key areas of progress that the private sector is making in space and space-related technologies, while also seeing the shift in how the DoD approaches innovation and acquisition.

Dr. Frank Hoffman, a Senior Research Fellow at the Center for Strategic Research and Book Review Editor for *Joint Force Quarterly* agrees. In his review of the article he believes, "This assessment must extend beyond the Pentagon as well, to include the rapidly expanding cast of governmental and nongovernmental space actors."[84] The article stresses the importance of technological innovation and acquisition for any advancing space strategy, stating, "Obviously, diplomacy must be underpinned by technological capabilities, both for deterrence and for hedging against threat breakout."[85]

Lt Col Peter Garretson, an Air University instructor with space acquisition experience, also believes that the DoD innovation and acquisition reform will vastly impact space security and U.S. national security. In an article he published, he says, "At

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[82] Heritage Foundation. Interview with Mr. Dean Cheng. Washington D.C., 2 March 2016.
[83] The Atlantic Council. *Atlantic Council Strategy Paper No.5, Toward a New National Security Space Strategy: Time for a Strategic Rebalancing.* Washington, D.C.: The Atlantic Council, (2016) i.
[84] Hoffman, Frank. Correspondence with Air University Research Team. 11 July 16.
[85] The Atlantic Council. *Atlantic Council Strategy Paper No.5, Toward a New National Security Space Strategy: Time for a Strategic Rebalancing.* Washington, D.C.: The Atlantic Council, (2016) i.

present, the United States stands at a moment of opportunity. Our nation has a clear lead on re-usable launch vehicles (RLVs). The highly visible demonstrations of SpaceX and Blue Origin are just the observable portion of a much larger iceberg of commercial ambitions and industrial capabilities. With the right policies, regulation, incentives, and anchor contracts we can consolidate this early lead into a US-owned, fully re-usable launch system capable of simultaneously lowering the price of access to space and increasing the frequency of access to space."[86] Lt Col Garretson believes that the shift in DoD innovation and acquisition strategy directly applies to lowering the cost to access space.

The foundational principles of innovation and acquisition strategy that Posen and Rosen highlight are changing due to a shift in the character of warfare.[87] Peacetime is becoming more challenging to distinguish from wartime environments.[88] An absolute in either environment may become a distant memory to future generations. As this shift in warfare occurs, leaders in multiple fields have identified opportunities for the United States to take advantage of. Secretary of Defense Carter has shifted the DoD's organizational innovation and acquisition model with DIUx and MD5. Think tanks and academia are championing new strategies to quickly take advantage of emerging technologies. Strategists like Lt Col Garretson are beginning to connect all the pieces,

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[86] Garretson, Lt Col Peter, USAF. *The United States Must Consolidate Ultra-Low-Cost Access to Space (ULCATS).* Leading Edge, Airpower in Theory and Practice, 8 June 2015. https://leadingedgeairpower.com/2016/06/08/the-united-states-must-consolidate-ultra-low-cost-access-to-space-ulcats/

[87] Heritage Foundation. Interview with Ms. Michaela Dodge. Washington D.C., 2 March 2016.

[88] Heritage Foundation. Interview with Ms. Michaela Dodge. Washington D.C., 2 March 2016.

calling for investment strategies that will lower the cost to access space. The question remains, however…how will lowering the cost to access space impact the mission of the United States Air Force?

Chapter 8

United States Air Force Applications

Lowering the cost to access space will have internal policy implications for the United States Air Force and its future core missions.[1] As the cost to access space is lowered, the United States Air Force will have the opportunity to partner with civilian industries to influence future development.[2] In doing so, there is an opportunity to take advantage of current technologies to develop a platform capable of rapidly delivering mission sets of the United States Air Force through the space domain.[3] The Air Force Future Operating Concept outlines operational agility as the critical factor in its future core missions and warfighting ability.[4] The Air Force core missions of the future will be Adaptive Domain Control, Global Integrated Intelligence, Surveillance, and Reconnaissance, Rapid Global Mobility, Global Precision Strike, and Multi-Domain Command and Control.[5] As the cost to access space is lowered through key advancements in emerging technologies, the United States Air Force will be able to take advantage of new capabilities and platforms to achieve their core missions.[6] In doing so, the Air Force will be able to offer the joint force and national leadership new options to

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[1] Dolman, Everett. Interview conducted at Air University. Maxwell AFB, AL, 2 Dec 15.
[2] United States Air Force. *Military Spaceplane, Generating and Executing Combat Spacepower; Results of the AF-NASA 120 Day Study on RLV.* Washington, D.C.: Office of the Secretary of the Air Force, 2002.
[3] Baker, Jim. Comments made during meeting at Air University. Maxwell AFB, AL, Oct 15.
[4] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[5] Welsh, Mark A. III. *Air Force Future Operating Concept.* Washington: Office of the Chief of Staff of the Air Force, (2015) 8.
[6] Heritage Foundation. Interview with Mr. John Venable. Washington D.C., 2 March 2016.

apply to traditional strategies as well as expand defense strategies into new areas of discussion.[7]

Operational agility is a cornerstone of Adaptive Domain Control.[8] The Air Force Future Operating Concept defines Adaptive Domain Control as "the ability to operate in and across air, space, and cyberspace to achieve varying levels of domain superiority over adversaries seeking to exploit all means to disrupt friendly operations."[9] This core mission is essential to achieving the national security objectives of the United States. Through the use of an XS-1 or X-37B type space vehicle, the United States can use an asymmetric capability to complicate an adversary's decision making process. By manipulating distance and time, "the Air Force will be in an advantageous position to deliver its core mission effects across each domain."[10]

Global Integrated Intelligence, Surveillance, and Reconnaissance operations are an increasingly important core mission of the United States Air Force. The Air Force Future Operating Concept highlights that "GIISR continues to enable current and future operations through the cross-domain synchronization and integration of: planning and operation of ISR assets; collection using near-ubiquitous sensors; and processing,

[7] Baker, Jim. Comments made during meeting at Air University. Maxwell AFB, AL, Oct 15.
[8] Welsh, Mark A. III. *Air Force Future Operating Concept.* Washington: Office of the Chief of Staff of the Air Force, (2015) 4.
[9] Welsh, Mark A. III. *Air Force Future Operating Concept.* Washington: Office of the Chief of Staff of the Air Force, (2015) 18.
[10] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges. (*Maxwell AFB, AL: Air University, 2017) 26.

exploitation and dissemination (PED) of finished intelligence."[11] It is a key mission support area that links the other core missions together.

Rapid Global Mobility allows the United States to project global power. The Air Force Operating Concept states, "at its core, RGM has always focused on the relocation of manpower and physical materials, but this process now occurs through a much wider portfolio of physical—and virtual—methods across multiple domains."[12] Without Rapid Global Mobility, the United States does not have the ability to be a global presence.

Global Precision Strike remains the pinnacle core mission of the Air Force. The United States' evolution in this domain has allowed it to deter adversaries prior to conflict, and win the nation's wars if deterrence fails. However, the global strike mission has changed over time. The Air Force Future Operating Concept notes that "integration enable AF assets to conduct *integrated multi-domain* global precision strike using a *balanced capabilities mix* of forces, in collaboration with joint and multinational partners."[13] The ability to rapidly perform the global strike mission, to be rapidly present anywhere in the world, while intertwined with other core missions will continue to become more important in the future.

At the center of each core mission previously discussed is the core mission of Multi-Domain Command and Control. Rightfully, the Air Force Future Operating

[11] Welsh, Mark A. III. *Air Force Future Operating Concept.* Washington: Office of the Chief of Staff of the Air Force, (2015) 23.
[12] Welsh, Mark A. III. *Air Force Future Operating Concept.* Washington: Office of the Chief of Staff of the Air Force, (2015) 26.
[13] Welsh, Mark A. III. *Air Force Future Operating Concept.* Washington: Office of the Chief of Staff of the Air Force, (2015) 30.

Concept describes command and control as "fundamental to military operations."[14] Command and control enables the other core missions to execute effectively. Unfortunately, adversaries of the United States are actively working to prevent the armed forces from achieving their core missions.

As the cost to access space lowers, accomplishing these core missions in and through space is feasible. For instance, rapidly delivering United States Air Force core mission effects to a remote location in support of threatened embassy personnel is a valid mission for this type of capability. The launch of a space vehicle from the continental United States could have the ability to deliver surveillance, communications, resupply, or strike assets. The attack on the United States embassy in Benghazi is an example where this would be beneficial.[15] In this scenario, the goal of the United States was deescalating the situation in support of personnel on the ground so that evacuation could occur and diplomatic efforts could be the primary instrument of power in use.[16] De-escalation can occur in the form of limited strike, maneuver of personnel with intelligence from quickly delivered assets, or non-kinetic engagement of adversaries.[17] The critical factor in the Benghazi scenario was the limited amount of time that embassy personnel had to react, and in turn the United States military's response. A space vehicle takes advantage of orbital factors to influence the notion of time in maneuver warfare.

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[14] Welsh, Mark A. III. *Air Force Future Operating Concept.* Washington: Office of the Chief of Staff of the Air Force, (2015) 14.
[15] LeMay Center Wargaming Directorate. *A Rapid Global Effects Capability Concept Wargame After Action Report.* Maxwell Air Force Base, AL, 22 October 2015.
[16] LeMay Center Wargaming Directorate. *A Rapid Global Effects Capability Concept Wargame After Action Report.* Maxwell Air Force Base, AL, 22 October 2015.
[17] LeMay Center Wargaming Directorate. *A Rapid Global Effects Capability Concept Wargame After Action Report.* Maxwell Air Force Base, AL, 22 October 2015.

The application of maneuver warfare to the space domain is also important. A space vehicle like XS-1 has the capability to replenish satellites that reach their end of useful life cycles.[18] Additionally, the same space vehicle has the ability to rapidly replenish comprised satellite assets that are either damaged by space debris or suffered from an adversary's offensive action. This type of rapid reconstitution of space assets changes the strategic calculus of space, both for allies and adversaries of the United States.[19] It will take the vision and leadership of current and future generations for the United States to maintain its competitive advantages.

An important aspect to future investment is the potential inspiration that the United States Air Force will have on the future generations of leaders. A research study was conducted with the Auburn University Air Force ROTC Detachment. The intent of the research was to brief the detachment on the potential United States Air Force applications of low-cost access to space, various concepts, and receive feedback from a generational and inspirational perspective.

The following questions were asked of the cadets in a survey and their responses are annotated:

- Does this inspire the next generation of Air Force Leaders?
  - 100% (64 out of 64) said they were inspired[20]
- Does this motivate you to join/stay in the Air Force?

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[18] LeMay Center Wargaming Directorate. *A Rapid Global Effects Capability Concept Wargame After Action Report.* Maxwell Air Force Base, AL, 22 October 2015.
[19] LeMay Center Wargaming Directorate. *A Rapid Global Effects Capability Concept Wargame After Action Report.* Maxwell Air Force Base, AL, 22 October 2015.
[20] Auburn University ROTC Detachment After Action Report. Air University, Maxwell AFB, AL 10 March 2016.

- 95% (61 out of 64) said this motivates them to join/stay in the Air Force[21]

- Would you want to be a part of this concept?
  - 94% (60 out of 64) said they would want to be a part of this concept[22]

- What is one word you would use to describe this concept (some words were used more than once)?
  - Wow, Efficient, Deadly, Innovating, Thrilling, Air Superiority, Intimidating, Futuristic, Interesting, Future, Exciting, Effective, Superior, Intriguing, Capability, Revolutionary, Expensive, Powerful, New-Age, Powerful, Controversial, Mind-Blowing, The Future, Intriguing, Awesome, Ambitious, Cool[23]

Overall, the cadets at the Auburn ROTC Detachment were very receptive and motivated about lowering the cost to access space and potential concept platforms associated with emerging technologies, such as XS-1. The ability for the United States Air Force to attract and retain the best and brightest leaders from around the world is the cornerstone of success.[24] As noted in previous discussions about innovation and acquisition, having senior officers with the appropriate vision for the future and understanding of emerging technologies advocate for the correct investment strategies is important for the evolution of the United States Air Force.[25] However, just as important

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[21] Auburn University ROTC Detachment After Action Report. Air University, Maxwell AFB, AL 10 March 2016.
[22] Auburn University ROTC Detachment After Action Report. Air University, Maxwell AFB, AL 10 March 2016.
[23] Auburn University ROTC Detachment After Action Report. Air University, Maxwell AFB, AL 10 March 2016.
[24] Auburn University ROTC Detachment After Action Report. Air University, Maxwell AFB, AL 10 March 2016.
[25] Miller, Charles. Interview at Brookings Institute. Washington, D.C., 19 May 16.

is the opinion of the most junior members of the armed forces. In an era of rapidly evolving technology, these members of the armed forces will often understand the latest trends and capabilities better than the most senior officers. Also, they lack institutional or personal bias that subconsciously develops over time. Therefore, the opinion of the Auburn cadets warrants consideration and is a valuable research point. A strategy of investing in capabilities that achieve decisive effects against adversaries while inspiring current and future generations is a prudent course of action for the United States Air Force.[26]

Few people can truly envision the potential impact of an XS-1 platform, or similar capability, and how to properly employ it. In an effort to bridge the gap between today's core missions and the core missions of the future, the United States Air Force Wargaming Institute conducted a wargame on the potential impact of a platform like XS-1.

United States Air Force Wargame Results

The Air Force Research Laboratory and Air University sponsored a wargame in June of 2015 to determine how a platform like XS-1, with the capability to rapidly deliver global effects, would impact the Air Force core mission set. The wargame team traveled to four locations to conduct research: Air Mobility Command, Air Force Space Command, Air Force Global Strike Command, and the Air Warfare Center at Nellis Air Force Base. Their research found that 92% of participants either "Agreed" or "Strongly

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[26] Baker, Jim. Comments made during meeting at Air University. Maxwell AFB, AL, Oct 15.

Agreed" that the ability to rapidly deliver global effects through an XS-1 type platform was relevant to their mission set.[27]

Participants agreed that the concept would be most effective in conventional strike, command and control, intelligence, surveillance, and reconnaissance, and humanitarian relief missions. Particularly, participants believed that time sensitive missions and targets are uniquely suited to be matched with a platform with the ability to provide rapid global effects.[28] In a fiscally constrained environment, this may augment current conventional forces in achieving current and future missions. There is a counter-argument as to what current assets or fiscal policies may change in order to invest in the development of a platform capable of providing rapid global effects. While outside the scope of this research, it warrants a discussion at the service and department levels when prioritizing strategic investment strategies.

There were areas, however, that the participants agreed the concept should not be used. Most participants agreed that the concept should not be used for nuclear weapons transport or employment. These participants had concerned over the security of nuclear weapons or components of nuclear weapons until an appropriate reliability rate is achieved. For instance, a reliability rate of aircraft-like performance is required for nuclear weapons transport, in their opinion. Participants also questioned the signaling to

[27] LeMay Center Wargaming Directorate. *A Rapid Global Effects Capability Concept Wargame After Action Report.* Maxwell Air Force Base, AL, 22 October 2015.
[28] LeMay Center Wargaming Directorate. *A Rapid Global Effects Capability Concept Wargame After Action Report.* Maxwell Air Force Base, AL, 22 October 2015.

adversaries that the concept could make as well as the question of stabilizing versus destabilizing effects.[29]

Each group of participants also brought up the ability of a platform capable of rapidly delivering Air Force core mission effects to deliver drone technology in future strike packages. For instance, a 20,000 pound payload could deliver 20 remotely-piloted aircraft;[30] each with differing capabilities to include strike, communications nodes, and intelligence, surveillance, and reconnaissance.[31] In effect, an XS-1 or similar platform could deliver an autonomous strike package with a degree of artificial intelligence in which each drone could communicate to the others.[32] They could have the ability to operate independently or in an autonomous swarm.[33] A counter-argument is that remotely-piloted assets can be delivered by air or sea-based platforms. However, this also creates traditional logistics lines of support. A CONUS-based platform that takes advantage of the space domain limits traditional logistics lines that become expensive.[34] This type of capability complements other technologies that are emerging, particularly

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[29] LeMay Center Wargaming Directorate. *A Rapid Global Effects Capability Concept Wargame After Action Report.* Maxwell Air Force Base, AL, 22 October 2015.
[30] Hellman, Barry and St. Germain, Dr. Brad. *Initial Analysis of Concepts for Air Guardian.* Wright-Patterson AFB, OH, 10 Feb 15.
[31] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[32] Price, Walter. Interview conducted at Air Force Global Strike Command Wargame. Maxwell AFB, AL, 9 Dec 15.
Buschur, Maj Brian. Interview conducted at Air Force Global Strike Command Wargame. Maxwell AFB, AL, 9 Dec 15.
Caffrey, Matt. Interview conducted at Air Force Global Strike Command Wargame. Maxwell AFB, AL, 9 Dec 15.
[33] LeMay Center Wargaming Directorate. *A Rapid Global Effects Capability Concept Wargame After Action Report.* Maxwell Air Force Base, AL, 22 October 2015.
[34] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.

the technologies that Deputy Secretary of Defense Work has said will be critical to the Department of Defense's future strategies.[35]

In an effort to further explore the lessons learned from the Air Force's Wargaming efforts, interviews were conducted with key staff members of United States Air Forces Europe (USAFE). Those staff members have articulated the potential benefits that a platform capable of rapid global effects could bring to the challenges they face in their theater. Key areas of discussion were USAFE Presence/Posture, Command and Control/Command Relationships (C2/COMREL), Basing, Force Structure, and Interoperability.

In discussions involving the United States' military involvement in Europe, there is and has been in the past a balance between presence and posture.[36] Each office at USAFE is addressing to some extent a decreasing U.S. presence in Europe. Members cite basing and personnel downsizing as concerns.[37] Members also cite concerns over the signaling that deployment of the A-10 to Europe sends to potential adversaries.[38] In April of 2015, "demonstrating its commitment to a 'free' and 'secure' Europe, the United States deployed 12 F-15C Eagles and approximately 350 Airmen to Iceland and the Netherlands."[39] The United States Air Force is deploying weapons systems,

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[35] Colby, Elbridge. *The Implications of the Commercialization of Space and ULCATS for a U.S. Limited War Defense and Deterrence Strategy for Space.* Washington, D.C.: Center for a New American Security, Nov 16.
[36] McNulty, Brian. Interview conducted at Headquarters, United States Air Forces Europe. Ramstein Air Base, Germany, 8 Feb 16.
[37] Moore, Theresa. Interview conducted at Headquarters, United States Air Forces Europe. Ramstein Air Base, Germany, 9 Feb 16.
[38] Hinders, Steven. Interview conducted at Headquarters, United States Air Forces Europe. Ramstein Air Base, Germany, 9 Feb 16.
[39] Cohen, Zachary. *U.S. F-15's deployed to Iceland.* Atlanta, GA: Cable News Network, 3 April 2016.

maintenance, and support personnel to Europe to deter Russian aggression and assure its allies.[40] This is both time-consuming for personnel and expensive. This leads to a discussion for policy makers and senior military leaders about the proper balance between presence and posture. USAFE personnel interviewed believe that the ability to accomplish the future United States Air Force core missions in and through space will aid in the discussion on the proper balance between presence and posture.[41]

With respect to a platform with the capability to rapidly deliver global effects, members note that its posture could offer a balance to changes in U.S. presence in Europe.[42] They believe that posturing with CONUS assets that have the ability to rapidly respond to combatant commanders critical needs holds merit in the overall presence/posture dilemma. However, those interviewed also caution that posturing an asset like an XS-1 or similar platform comes with C2/COMREL challenges.[43]

Emerging technologies are presenting challenges to USAFE command and control dynamics as well as command relationships. For instance, USAFE members highlight how the operation of remotely piloted aircraft (RPA's) have outpaced current Air Force and Joint Doctrine.[44] USAFE is at the leading edge in this field and are solving

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[40] Jones, Capt Chris. Interview conducted at Headquarters, United States Air Forces Europe. Ramstein Air Base, Germany, 8 Feb 16.

[41] McNulty, Brian. Interview conducted at Headquarters, United States Air Forces Europe. Ramstein Air Base, Germany, 8 Feb 16.; Jones, Capt Chris. Interview conducted at Headquarters, United States Air Forces Europe. Ramstein Air Base, Germany, 8 Feb 16.; Hinders, Steven. Interview conducted at Headquarters, United States Air Forces Europe. Ramstein Air Base, Germany, 9 Feb 16.

[42] McNulty, Brian. Interview conducted at Headquarters, United States Air Forces Europe. Ramstein Air Base, Germany, 8 Feb 16.

[43] McNulty, Brian. Interview conducted at Headquarters, United States Air Forces Europe. Ramstein Air Base, Germany, 8 Feb 16.

[44] McNulty, Brian. Interview conducted at Headquarters, United States Air Forces Europe. Ramstein Air Base, Germany, 8 Feb 16.

doctrinal challenges at the tactical and operational level in order to support commander and warfighter needs. Currently, RPA's are controlled from CONUS and launched from Europe while in support of three different commands[45] (USAFE, AFRICOM, and CENTCOM).[46] Current RPA operations represent a High Demand/Low Density challenge that USAFE personnel believe space vehicle can help with. USAFE personnel also believe a space vehicle capable of delivering United States Air Force core mission effects will be able to help with Ballistic Missile Defense.

NATO's Ballistic Missile Defense (BMD) C2 structure has current challenges. The U.S. must rely on coalition BMD capabilities to mitigate the High Demand/Low Density asset challenge.[47] This issue has become more problematic due to recent refugee migrations from areas of conflict throughout the Middle East to Europe. In the past, NATO nations have agreed to contribute two percent of each country's gross domestic product to the collective defense of the alliance. Allies to the United States in NATO, now strained with millions of refugees, are finding it difficult to maintain this spending rate on defense.[48]

Emerging technologies will continue to test C2, COMREL, and current doctrinal policies. USAFE members note that a platform with the ability to rapidly deliver global effects through space will have similar challenges to the RPA community in each of these

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[45] Currently, Remotely Piloted Aircraft are launched from Europe and flown to geographic areas in USAFE, AFRICOM, and CENTCOM.
[46] McNulty, Brian. Interview conducted at Headquarters, United States Air Forces Europe. Ramstein Air Base, Germany, 8 Feb 16.
[47] Jones, Capt Chris. Interview conducted at Headquarters, United States Air Forces Europe. Ramstein Air Base, Germany, 8 Feb 16.
[48] Smeeth, Craig. Interview conducted at Headquarters, United States Air Forces Europe. Ramstein Air Base, Germany, 8 Feb 16.

areas, both within CONUS and in various geographic areas throughout the world. USAFE members note that this type of platform may be able to aid in the BMD challenges that USEUCOM is facing. Sacrificing a window of time in order to position critical assets away from BMD duties may be a tradeoff that NATO leadership is willing to take. The U.S. would have the ability to maintain its deterrent capability while ensuring allies with a diverse platform and a different response window.[49]

USAFE is currently undergoing a wide-range of basing changes to support its force of the future. USAFE is currently divesting RAF Mildenhall, RAF Alconbury-Molesworth, and streamlining Lajes AB. Upgrade projects include Special Operations facilities at Spangdahlem AB and tanker facilities at Ramstein AB. Challenges include funding, RC-135 host nation sensitivities, and high-density operations in Germany.[50]

Changes in basing are representative of the challenges that USAFE is facing with presence. A capability to rapidly deliver global effects has the ability to offer operational flexibility from CONUS for USAFE that will help alleviate some basing challenges.[51] USAFE members cite that a this type of capability would alleviate host nation sensitivity to RC-135 basing and operational employment. Basing of the RC-135 has become a sensitive issue due to previous allegations that the United States used various means to collect intelligence on allies. Also, with additions to basing structures in Germany, USAFE members note that congested airspace is becoming an issue for joint training and

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[49] McNulty, Brian. Interview conducted at Headquarters, United States Air Forces Europe. Ramstein Air Base, Germany, 8 Feb 16.
[50] Moore, Theresa. Interview conducted at Headquarters, United States Air Forces Europe. Ramstein Air Base, Germany, 9 Feb 16.
[51] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.

operational missions. Utilizing a CONUS-based platform for some missions would enable other legacy platforms to perform more high-demand missions for the major and combatant commanders.[52]

USAFE team members also note that the capability to deliver global effects rapidly could impact force structure. An example of current force structure challenges at USAFE is the alert posture of two C-130 aircraft at Ramstein AB in the "New Normal Now" structure.[53] The alert posture allows USAFE to respond to contingency operations in USAFE and AFAFRICA. Thus, two aircraft are unavailable for other daily missions in order to support the alert tasking. Depending on the requirement, a CONUS-based platform could deliver equipment and supplies to a remote location in Africa through the space domain. A rapid global effects capability will allow greater operational agility while potentially returning two C-130's, associated aircrews, maintenance, and support personnel to immediate needs within USAFE. USAFE members also note that it will also allow for a more immediate response to contingencies in which traditional assets may not even have the ability to support (due to large distances in Africa).[54]

USAFE operations are always concerned with interoperability with NATO partners.[55] USAFE professionals caution to consider how a platform that utilizes the

[52] Moore, Theresa. Interview conducted at Headquarters, United States Air Forces Europe. Ramstein Air Base, Germany, 9 Feb 16.
[53] Hall, Lt Col Shane. Interview conducted at Headquarters, United States Air Forces Europe. Ramstein Air Base, Germany, 8 Feb 16.
[54] Hall, Lt Col Shane. Interview conducted at Headquarters, United States Air Forces Europe. Ramstein Air Base, Germany, 8 Feb 16.
[55] Hinders, Steven. Interview conducted at Headquarters, United States Air Forces Europe. Ramstein Air Base, Germany, 9 Feb 16.

space domain may interoperate with NATO partners.[56] For instance, should this type of capability base and operate from Lajes AB? What are the C2 implications in NATO for a CONUS-based space platform that has the ability to rapidly deliver effects anywhere in the world? These are credible questions that the United States should consider when developing future concepts.

The areas that USAFE interviewees highlight are applicable to other commands and the United States Air Force at large. They particularly highlight how new and future technologies will test our current doctrine models while alleviating some challenges and providing support to warfighters and commanders. Additionally, they point to how these emerging technologies will impact domestic and international policy.

Policy Implications Concerning Near-Peer Adversaries—China and Russia

Recently, the Vice-Chairman of the Joint Chief of Staff said that Russia was the number one existential threat to the United States.[57] Many other strategists believe China to be the number one long-term threat to the United States.[58] Each country provides specific, yet sometimes similar, threats to the United States.

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[56] McNulty, Brian. Interview conducted at Headquarters, United States Air Forces Europe. Ramstein Air Base, Germany, 8 Feb 16.

[57] Selva, General Paul J. *Trends in Military Technology and the Future Force.* Comments made at the Brookings Institution. Washington D.C., 21 Jan 16.

[58] Heritage Foundation. Interview with Mr. Dean Cheng. Washington D.C., 2 March 2016.
Heritage Foundation. Interview with Mr. John Venable. Washington D.C., 2 March 2016.
Heritage Foundation. Interview with Ms. Michaela Dodge. Washington D.C., 2 March 2016.

China is expanding its sphere of influence regionally.[59] China is currently interested in expanding into the South China Sea.[60] They are doing so because of a ballooning population that they need to support with natural resources. Also, China is interested in the military advantages that the South China Sea possesses.[61]

The South China Sea has important strategic implications. Robert Kaplan notes that "the South China Sea functions as the throat of the Western Pacific and Indian oceans—the mass of connective economic tissue where global sea routes coalesce."[62] It also has substantial oil reserves that serve China's economic development interests.[63] Militarily, the South China Sea forms a geographic barrier to potential invasion of China.[64]

China is creating an Anti-Access Area Denial environment in the South China Sea.[65] Kaplan notes that "domination of the South China Sea would certainly clear the way for pivotal Chinese air and naval influence throughout the navigable rimland of

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[59] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[60] Heritage Foundation. Interview with Mr. Dean Cheng. Washington D.C., 2 March 2016.
[61] Center for a New American Security. Interview with Mr. Jerry Hendrix. Washington D.C., 2 March 2016.
Center for a New American Security. Interview with Ms. Kelley Slayer. Washington D.C., 2 March 2016.
[62] Kaplan, Robert D. *Asia's Cauldron: The South China Sea and the End of a Stable Pacific.* New York, NY: Random House, (2014) 9.
[63] Heritage Foundation. Interview with Mr. Dean Cheng. Washington D.C., 2 March 2016.
[64] Heritage Foundation. Interview with Mr. Dean Cheng. Washington D.C., 2 March 2016.
[65] Baker, Jim. Comments made during meeting at Air University. Maxwell AFB, AL, Oct 15.

Eurasia—the Indian and Pacific oceans both."[66] Russia is also presenting strategic problems for the United States and putting stress on the national security objectives of the United States.[67]

Russia has shown recent military aggression in both Georgia and the Ukraine. In each instance, the international community condemned the actions but did little militarily to respond.[68] Economic sanctions of Russian banks and key leaders were the major response that the international community imposed for each aggression. The international community believed its options were limited and took little to no military options, fearing conflict escalation.[69]

Russia has also projected global power into the Middle East in the Syrian conflict and the fight against the Islamic State in Iraq and Syria.[70] Fareed Zakaria notes that "global power is, above all, dominance over ideas, agendas, and models."[71] Russia is attempting to dominate the agenda in the Middle East and assert its influence. Again, the United States believes that it has few options to counter this power projection threat.

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[66] Kaplan, Robert D. *Asia's Cauldron: The South China Sea and the End of a Stable Pacific.* New York, NY: Random House, (2014) 49.

[67] Colby, Elbridge. *The Implications of the Commercialization of Space and ULCATS for a U.S. Limited War Defense and Deterrence Strategy for Space.* Washington, D.C.: Center for a New American Security, Nov 16.

[68] Center for a New American Security. Interview with Mr. Jerry Hendrix. Washington D.C., 2 March 2016.

[69] Heritage Foundation. Interview with Mr. John Venable. Washington D.C., 2 March 2016.

[70] Star, Barbara and Lendon, Brad. *Russian fighter came within 15 feet of U.S. Air Force jet.* Atlanta, GA: Cable News Network, 30 Jan 16.

[71] Zakaria, Fareed, *The Post-American World* (Release 2.0), New York: W.W. Norton, (2011) 49.

Emerging technology will allow the United States armed forces to achieve their future core missions with operational agility.[72] In doing so, the armed forces will offer the U.S. leadership a more expansive list of options to choose from.[73] Ultimately, the objective of investment in emerging technology is peace through deterrence while achieving the national security objectives of the United States.[74] The ability to rapidly deliver global effects will aid in this effort.[75]

A rapid global effects capability will mitigate China's A2AD environment.[76] It will offer an asymmetric advantage that the Chinese will have to consider in their strategic investments in the future.[77] The Chinese attempt to create a defensive barrier with land-based missiles in the South China Sea is a moot point considering CONUS-based assets that have the ability to operate in and through the space domain.[78]

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[72] United States Air Force. *Military Spaceplane, Generating and Executing Combat Spacepower; Results of the AF-NASA 120 Day Study on RLV.* Washington, D.C.: Office of the Secretary of the Air Force, 2002.

[73] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.

[74] Dolman, Everett. Interview conducted at Air University. Maxwell AFB, AL, 2 Dec 15.

[75] Center for a New American Security. Interview with Mr. Jerry Hendrix. Washington D.C., 2 March 2016.

[76] Baker, Jim. Comments made during meeting at Air University. Maxwell AFB, AL, Oct 15.

[77] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.

[78] Baker, Jim. Comments made during meeting at Air University. Maxwell AFB, AL, Oct 15.

Figure 34-Coverage Expansion from S-400 SAM and J-10 Deployment to South China Sea Airfields

Source: Corr, Andrew and Michaelides, Matthew. *Effect of South China Sea Air Strips on the Range of Chinese Surface-to-Air Missiles and the J-10 Fighter.* The Journal of Political Risk, 5 May 15.

For instance, a future platform launched from CONUS delivers a swarm of autonomous CLEAVER drones and aids in negating specific areas of China's A2AD environment.[79] The CLEAVER swarm will use operational agility and maneuver to overwhelm China's defenses.[80] There is a counter-argument that CLEAVER assets could be delivered by current conventional assets, such as a C-17 or B-52. Based on wargames that have been conducted, however, this severely limits the range and available targets.[81]

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[79] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[80] LeMay Center Wargaming Directorate. *A Rapid Global Effects Capability Concept Wargame After Action Report.* Maxwell Air Force Base, AL, 22 October 2015.
[81] Ideas and information for this paragraph were inspired from wording used from LeMay Center Wargaming Directorate personnel in 2015 and 2016.

These technologies will have the ability to achieve any of the Air Force future core missions.[82] As a result, it will also achieve the United States national security objectives in promoting and ensuring global access to sea lines of communications and natural resources in the South China Sea.[83] These technologies will deter aggression from Russia as well.[84]

As noted previously, there were little to no options to stop Russian aggression in Ukraine and Georgia.[85] Many feared escalating the situation, so the response from the United States militarily was to do nothing. The launch of a Rapid Global Effects Capability to deliver an autonomous swarm of CHAMP cruise missiles could have a stabilizing effect.[86] Dr. Everett Dolman notes that this could also have a destabilizing effect.[87] However, as Mr. Jim Baker, the Director of the Office of Net Assessment points out, this would be no more of a destabilizing effect than the development and overseas employment of the F-35.[88] Experts disagree as to the range of stabilizing versus

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82 Ideas and information for this paragraph were inspired from wording used from LeMay Center Wargaming Directorate personnel in 2015 and 2016.

83 Baker, Jim. Comments made during meeting at Air University. Maxwell AFB, AL, Oct 15.

84 Baker, Jim. Comments made during meeting at Air University. Maxwell AFB, AL, Oct 15.

85 Smith, Michael. Interview at Brookings Institute. Washington, D.C., 19 May 16.

86 Heritage Foundation. Interview with Mr. John Venable. Washington D.C., 2 March 16.

87 Dolman, Everett. Interview conducted at Air University. Maxwell AFB, AL, 2 Dec 15.

88 Baker, Jim. Comments made during meeting at Air University. Maxwell AFB, AL, Oct 15.

destabilizing effect that this capability could have. It is safe to say that this capability would need to be part of an overall strategy involving the other instruments of power.[89]

A Rapid Global Effects Capability could deliver directed energy weapons to eliminate any electronic capability that advancing Russian forces were using.[90] The combination of these emerging technologies could make a Russian Surface-to-Air threat noted below virtually non-existent.[91] (See current Russian SAM Capabilities and maps.)

Missile Name	Range(nm)	Max Alt (ft)	Speed (Mach)	ABM (nm)	IOC	Notes
SA-2 Guideline	23.2	90,000	3.5	N/A	1959	
SA-3 Goa	15.7	60,000	3.5	N/A	1961	
SA-5 Gammon	162	115,000	3.5+	N/A	1967	
SA-6 Gainful	16	43,000	1.8	N/A	1979	
SA-7 Grail	3.5	15,000	1.7	N/A	1966	MANPAD
SA-8 Gecko	8.6	37,000	2.4	N/A	1975	
SA-9 Gaskin	4.3	26,000	1.8	N/A	1968	
SA-10 Grumble	49	82,000	5+	19	1980	ACM
SA-11 Gadfly	17.3	62,000	3	N/A	1983	
SA-12A Gladiator	40.5	82,000	5.75	UNK	1987	
SA-12B Giant	54	98,400	8	21.6	1992	AHV, ABM
SA-13 Gopher	2.7	12,000	2	N/A	1978	
SA-14 Gremlin	3.2	18,000	1.75	N/A	1978	MANPAD
SA-15 Gauntlet	6.5	20,000	3	UNK	1990	ACM, APGM
SA-16 Gimlet	3.1	12,000	1.7	UNK	1986	MANPAD
SA-17 Grizzly	28	82,000	3.5	12.5	1998	
SA-18 Grouse	3.2	11,000	UNK	UNK	1983	MANPAD
SA-19 Grison	7.5	20,000	3.3	N/A	1998	
SA-20A Gargoyle	80	89,000	8.2	22	1993	ACM
SA-20B	124	89,000	8.8	22	1997	ABM
SA-21 Growler	216	115,000	UNK	UNK	2007	AHV, ABM

Table 1: Russian SAM Capabilities

Source: Writer, Staff. *Anti-Aircraft Systems.* 2012. http://www.militaryperiscope.com/weapons/missrock/antiair (accessed 24 Feb 16).

89 Colby, Elbridge. *The Implications of the Commercialization of Space and ULCATS for a U.S. Limited War Defense and Deterrence Strategy for Space.* Washington, D.C.: Center for a New American Security, Nov 16.
90 Baker, Jim. Comments made during meeting at Air University. Maxwell AFB, AL, Oct 15.
91 Baker, Jim. Comments made during meeting at Air University. Maxwell AFB, AL, Oct 15.

Figure 35 – Russian Surface-to-Air Missile Coverage

Source: Graphic provided by RussianDefence.net

This could de-escalate a Russian advance and create a situation for the Russians to either escalate or retreat.[92] Escalation may be a cost too high for the Russians.[93] Having escalation dominance in uncertain situations is very beneficial for the United States.[94] Perhaps nonlethal effects delivered outside Russia against Russian-supported

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[92] United States Air Force. *Military Spaceplane, Generating and Executing Combat Spacepower; Results of the AF-NASA 120 Day Study on RLV.* Washington, D.C.: Office of the Secretary of the Air Force, 2002.
[93] Colby, Elbridge. *The Implications of the Commercialization of Space and ULCATS for a U.S. Limited War Defense and Deterrence Strategy for Space.* Washington, D.C.: Center for a New American Security, Nov 16.
[94] Baker, Jim. Comments made during meeting at Air University. Maxwell AFB, AL, Oct 15.

forces would prevent an escalated response.[95] Research has, however, exposed some policy questions concerning both China and Russia.

Many interviewees questioned basing a platform that takes advantage of the space domain to deliver strategic effects solely in the continental United States. It was widely agreed that this basing dynamic would drastically reduce overseas basing and logistics costs, as well as the personnel strain of members of the armed forces living overseas. However, a CONUS-based system leaves the only available target for adversaries within CONUS.[96] Interviewees consider this to be a destabilizing aspect of the system.[97] They recommend considering the placement of this type of platform within allied countries such as Great Britain and Australia. Other sites recommended for basing included the Ascension Islands in the Atlantic Ocean, Guam Air Base in the Pacific Ocean, and Diego Garcia Air Base in the Indian Ocean, reducing the risk of an adversary striking CONUS. This also provides for operational agility through global presence. However, this would create additional logistics considerations that a CONUS-based system would not encounter. Signaling is also a concern that some mention in association with a platform that can deliver global effects rapidly through space.[98]

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[95] Dolman, Everett. Interview conducted at Air University. Maxwell AFB, AL, 2 Dec 15.

[96] Heritage Foundation. Interview with Mr. Dean Cheng. Washington D.C., 2 March 2016.
Heritage Foundation. Interview with Mr. John Venable. Washington D.C., 2 March 2016.
Heritage Foundation. Interview with Ms. Michaela Dodge. Washington D.C., 2 March 2016.

[97] Dolman, Everett. Interview conducted at Air University. Maxwell AFB, AL, 2 Dec 15.

[98] LeMay Center Wargaming Directorate. *A Rapid Global Effects Capability Concept Wargame After Action Report.* Maxwell Air Force Base, AL, 22 October 2015.

In the Wargame that the United States Air Force conducted in June of 2015, tactical experts cited signaling as one of their main concerns for the operational use of a platform that can takeoff or launch into space. Quite simply, would allies and adversaries detect the launch of this concept and misinterpret it as a nuclear intercontinental ballistic missile launch? This is a valid question and concern for a number of reasons.

Near-peer adversaries such as China and Russia would be able to distinguish between the launch of this type of platform and an ICBM.[99] Types of fuel used for propulsion, horizontal vs. vertical takeoff options, launch locations, and most importantly trajectory are factors that would distinguish between the two capabilities. The types of platforms that will take advantage of emerging technologies to create the ability to rapidly deliver global effects are being designed to launch into low earth orbit, while an ICBM goes into a much higher, elliptical 'flight path' in order to re-enter the atmosphere and strike its target.[100] Near-peer allies would also be able to distinguish between these launch factors as well as have the added benefit of potential intelligence sharing.

Adversaries that do not have the capabilities of China and Russia pose a separate challenge. Countries such as Iran and North Korea may not have the capability to distinguish between this type of platform and an ICBM launch. However, they do have considerable conventional military capabilities that they could utilize if they felt that they were a target of an ICBM.[101] The United States Air Force can address signaling concerns

[99] Sercel, Joel. *Sub-Orbital Transport, Air Force Guardian Program Concept Initial Feasibility Analysis.* ICS Associates Inc., 2016.
[100] Carsetter, Scott. Comments made at the Center for Strategic and Budgetary Analysis Space Workshop. Washington D.C., 9 and 10 Nov 15.
[101] Heritage Foundation. Interview with Mr. Dean Cheng. Washington D.C., 2 March 2016.

with horizontal takeoff capability, basing location decisions, doctrine that prevents the use of a space platforms with nuclear capabilities, and deception operations. Alternatively, the United States could opt to use space platforms and the current ICBM fleet to diversify its nuclear capability and present adversaries with more expansive dilemmas on how to counter United States nuclear doctrine and operations. Interviewees and wargame participants also brought up the issue of creating a potential arms race.

The concern of an arms race is a valid concern and one that military strategists and United States policy makers must consider. The United States, in general, has not been concerned with arms races in the past due to a dominating economic presence and historical success during the Cold War.[102] However, these aspects are not guarantees for success in the future.

Developing the capability to rapidly deliver global effects would have considerable impact on the future core missions of the United States Air Force.[103] A discussion about the tradeoff between investments in this future concept, legacy systems currently in use, and how each would complement each other moving forward is appropriate. While outside the scope of this study, the economic factors include impact on personnel, basing, and investment in other emerging technologies are all critical to the

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Heritage Foundation. Interview with Mr. John Venable. Washington D.C., 2 March 2016.

Heritage Foundation. Interview with Ms. Michaela Dodge. Washington D.C., 2 March 2016.

[102] Baker, Jim. Comments made during meeting at Air University. Maxwell AFB, AL, Oct 15.

[103] LeMay Center Wargaming Directorate. *A Rapid Global Effects Capability Concept Wargame After Action Report.* Maxwell Air Force Base, AL, 22 October 2015.

overall discussion. However, initial research[104] supports the conclusion that a developing the capability to rapidly deliver global effects, while enabling the future core missions, would give the United States Air Force flexibility in personnel decisions, basing options, and complement legacy systems in their current operations.[105] These aspects present a dilemma for China and Russia.

In terms of an arms race, China and Russia would face difficult investment decisions moving forward.[106] While possible, this hasn't been the case when considering strategic investments in platforms like the KC-46, F-35, or B-21. Policy makers in the United States have made strategic investments based on national security needs, with each investment leaning towards an offensive and deterrent capability. Potential adversaries have made considerable investments in creating A2/AD environments, particularly China.[107] A capability that can manipulate distance and time through the use of the space domain would severely disrupt those efforts.[108] Adversary decisions would have to be made of how to invest in order to counter that capability.[109] The most likely option is to develop some kind of defensive capability to limit its effectiveness. Thus,

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104 United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
105 Baker, Jim. Comments made during meeting at Air University. Maxwell AFB, AL, Oct 15.
106 Center for a New American Security. Interview with Mr. Jerry Hendrix. Washington D.C., 2 March 2016.
Center for a New American Security. Interview with Ms. Kelley Slayer. Washington D.C., 2 March 2016.
107 United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
108 United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
109 Baker, Jim. Comments made during meeting at Air University. Maxwell AFB, AL, Oct 15.

investment in a capability to deliver effects through space has the potential to become part of a greater cost-imposition strategy for the United States.[110] Ultimately, the United States' goal is to maintain the peace, creating a situation in which it holds the military advantage and is better able to influence adversaries with other instruments of power.

[110] Baker, Jim. Comments made during meeting at Air University. Maxwell AFB, AL, Oct 15.

Chapter 9

Implications

The research has found that as the cost to access space decreases, the United States Air Force will have the opportunity to achieve greater operational agility across future core missions.[1] Rapid access to space will have a significant impact on domestic and foreign policy.[2] Domestically, it will highlight a new era in Air Force technological investment and acquisition strategy while inspiring the youth of tomorrow. Foreign policy will shift with the impact on current treaties, a wide range of deterrent effects, and impact on combatant commander operational plans. For the Air Force core missions, new dimensions in the vertical nature of warfare will change dramatically while igniting a new interest both in space and in service to the nation.[3] Technological investment in capabilities that have the ability to access space rapidly will provide the President with more options through achieving operational agility. Operational agility allows for the armed forces to achieve their future core missions.[4] An example of this is the Air Force's 2035 core missions of Adaptive Domain Control, Global Integrated ISR, Rapid Global Mobility, Global Precision Strike, and Multi-domain Command and Control. In achieving their core missions, the United States armed forces ensure that the nation's national security objectives are achievable. This research has also identified key areas in

[1] Goldfein, David. Meeting conducted at the Pentagon. Washington, D.C., 7 Dec 15.
[2] Zimmerman, Robert. *Center for a New American Security Report on Capitalism in Space: Private Enterprise and Competition Reshape the Global Aerospace Launch Industry.* Washington, D.C.: CNAS, 2017.
[3] Meeks, Woodrow. (Ideas for this paragraph from a meeting on A Rapid Global Effects Capability, Air University, Maxwell AFB, AL, 21 October 2015).
[4] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.

which a Rapid Global Effects Capability may impact future operations in the European and Pacific theaters. This impact is possible through a new paradigm in commercial investment in technology while partnering with government and academic institutions.[5]

International laws and accepted norms of behavior will change as the cost to access space decreases. The 1967 Outer Space Treaty, Strategic Arms Limitation Talks (SALT-II), and Strategic Arms Reduction Treaty lay the foundation of how states operate in and through space. The international norms of behavior do not limit man's further journey into space. In fact, because laws governing space were developed in a bipolar world in the Cold War era, there is little that will limit an expansion into space, including the use of space platforms to achieve the United State Air Force core missions. There will be a cultural shift in how humankind views space due to advances in emerging technologies.

Current research and development in commercial industry has created an environment in which TRLs needed to drastically reduce the cost to access space via emerging technologies is readily at hand. ULA, SpaceX, Blue Origin, and Masten Space Systems are just a few of the private companies exploring technologies that will reduce the cost to access space. These companies are moving away from traditional launch platforms like the Delta and Atlas series of launch vehicles to capabilities like the Falcon 9.[6] SpaceX is able to deliver a credible capability at 1/10th the cost of NASA's approach

[5] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[6] Zimmerman, Robert. *Center for a New American Security Report on Capitalism in Space: Private Enterprise and Competition Reshape the Global Aerospace Launch Industry.* Washington, D.C.: CNAS, 2017.

with their Falcon 9.[7] DARPA is building upon the shift in launch theory to explore an aircraft-like space vehicle, the XS-1. The ultimate goal of military research and development is to field a space vehicle capable of rapid and agile response that can deliver United States Air Force core mission effects. This effort is significantly aided by a multitude of emerging technologies.

As part of a Department of Defense effort to expand interest in emerging technologies with military utility, Deputy Secretary of Defense Work outlined his five points of interest in emerging technologies. The Department of Defense is particularly focused on Learning Systems, Human-machine Collaboration, Human-machine Combat Teaming, Assisted Human Operations, and Networked-enabled, Cyber-hardened Autonomous Weapons.[8] These interests partner nicely with emerging technologies that industry is pursuing. Investment in autonomy, CLEAVER, CHAMP, CubeSats, and new spacesuits each have applicability to warfare and the Department of Defense's areas of interest. Each of these technologies will either lower the cost to access space or allow the United States Air Force to achieve their core missions in and through space. The cumulative effect of these emerging technologies is causing various government policy makers to take notice.

President Obama set the foundation for the future expectations of the United States in space when declaring that sending humans to Mars and returning them safely

[7] Sercel, Joel. *Sub-Orbital Transport, Air Force Guardian Program Concept Initial Feasibility Analysis.* ICS Associates Inc., 2016.
[8] Work, Deputy Secretary of Defense, Bob. Speech given at The Reagan National Defense Forum. California, 7 Nov 15.

was going to be a national goal.[9] President Trump has reiterated this goal in his vision of expanding the United States' space capabilities and infrastructure. With an eye of the shifting strategic environment and the manner in which technologies are developed, Senator John McCain has called for greater latitude for the services in the Department of Defense in the pursuit of emerging technologies.[10] Other lawmakers, as well, are calling for an expansion of space launch and exploration efforts. Congressman Jim Bridenstine is championing investment to lower the cost to access space. The cumulative effect of these statements represent a shift in government policy as it relates to views on space launch, acquisition, and operations. The United States government is beginning to demand a decrease in the cost to access space.[11] This is represented in the manner in which the United States is shifting its acquisition strategies.

Government and military professionals have identified a shift in the character of warfare in which the line between peacetime and wartime is blurred. Many believe that there may never be a definitive peacetime environment, if there ever was one. As such, the military is taking initiatives to alter its organizational structure and mindset in an effort to rapidly identify and acquire emerging technologies with national security implications that commercial industry is developing.[12] Two examples of an institutional shift are the creation of DIUx and MD5. These organizations represent the first efforts in

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[9] Obama, President Barack. *America Will Take Giant Leap To Mars.* Atlanta, GA: Cable News Network, 11 October 2016.
[10] McCain, John. *Remarks On Defense Acquisition Reform at the U.S. Chamber of Commerce.* Washington, D.C., 2015.
[11] Zimmerman, Robert. *Center for a New American Security Report on Capitalism in Space: Private Enterprise and Competition Reshape the Global Aerospace Launch Industry.* Washington, D.C.: CNAS, 2017.
[12] Oti, Enrique. *SECAF Visit Summary to DiUX.* Silicon Valley, CA: DIUx, 11 Jan 16.

a realignment of acquisition strategies for the Department of Defense. Moving forward, the military will expand partnership efforts with civilian industry, think tanks, and academia at large to increase acquisition agility.[13] There are broad implications for the United States Air Force as a result.

The combination of a shift in theory and strategy, redefining historical space access, industry research and development, emerging technologies, changing government policies, and new government acquisition efforts will lead to a decrease in the cost of access space and allow the United States Air Force to achieve its future core missions in and through space.[14] This conclusion is supported by multiple wargames, interviews, and surveys.[15] The ability to rapidly deliver core mission effects in and through space will have policy implications concerning near-peer adversaries like China and Russia. Utilizing space to influence time, speeding up the United States' ability to influence events, will allow for the control of the pace of escalation and the strategic narrative.[16]

Lowering the cost to access space will give the United States Air Force greater operational agility while increasing its ability to power project and influence world events. In doing so, the United States will change the strategic narrative associated with Anti-Access Area Denial environments. In order to take advantage of the shifting strategic environment, the United States Air Force should pursue lowering the cost to

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[13] Zimmerman, Robert. *Center for a New American Security Report on Capitalism in Space: Private Enterprise and Competition Reshape the Global Aerospace Launch Industry.* Washington, D.C.: CNAS, 2017.
[14] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[15] LeMay Center Wargaming Directorate. *A Rapid Global Effects Capability Concept Wargame After Action Report.* Maxwell Air Force Base, AL, 22 October 2015.
[16] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.

access space through a dedicated acquisition model outside of traditional government acquisitions modeling and timelines.[17] Proper investment with the appropriate amount of risk in order to fail early and smartly, driving advancement in the technological fields that the United States Air Force needs, is critical to success.[18] The United States Air Force should enable and partner with commercial industry leaders to field a fully operational aircraft-like space vehicle on a ten-year developmental timeline.[19] The United States Air Force should shift institutional acquisition norms and dedicate an Air Force Major or Lieutenant General as the Program Manager who reports directly to the Secretary or Deputy Secretary of Defense.[20] This level of commitment has historical precedence in the placement of General Bernard Schriever in Southern California to develop the United States Air Force's future Intercontinental Ballistic Missile program.[21] Today, his success is seen in one pillar of the United States' nuclear triad. Further shifts in institutional norms should come in the establishment of a dedicated field office in Seattle, WA, San Francisco, CA, or Los Angeles, CA. This office should be for the sole purpose of a developing the capability of rapidly delivering Air Force core missions effects in and through space and should not be co-located with other acquisition programs.[22] The

[17] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[18] Disbrow, Lisa. Meeting conducted at the Pentagon. Washington, D.C., 7 Dec 15.
[19] Timeline based on estimates from AFRL and SpaceWorks.
[20] Zimmerman, Robert. *Center for a New American Security Report on Capitalism in Space: Private Enterprise and Competition Reshape the Global Aerospace Launch Industry.* Washington, D.C.: CNAS, 2017.
[21] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[22] Zimmerman, Robert. *Center for a New American Security Report on Capitalism in Space: Private Enterprise and Competition Reshape the Global Aerospace Launch Industry.* Washington, D.C.: CNAS, 2017.

location will allow for daily interaction with the industries associated with development, while creating a necessary buffer between the development team and traditional military development protocols. This will allow the pursuit of the effort to fail early and smartly, creating agility in the process so that the program manager can redirect efforts easily. The field acquisition team should be cognitively diverse, with leaders assigned from various backgrounds (military, civilian, and academia), services, year groups, and be joint creditable.[23] The Program Manager (Major or Lieutenant General) should sign performance reports with the Additional Rater on performance reports being the Secretary or Under Secretary of Defense, Secretary of the Air Force, or Chief of Staff of the Air Force.[24] This statement mirrors recent realignment of DIUx, in which the unit now reports directly to the Office of the Secretary of Defense. This organizational shift provides for program legitimacy throughout the United States Air Force and ensures that the best in each career field/year group are placed on the field office team.

These actions will allow the United States Air Force to take advantage of investments in civilian industry to usher in a new era of low cost access to space.[25] In doing so, Air Force core mission effects will be achievable in and through space, creating new opportunities for the United States while complicating the decision matrix of

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[23] Zimmerman, Robert. *Center for a New American Security Report on Capitalism in Space: Private Enterprise and Competition Reshape the Global Aerospace Launch Industry.* Washington, D.C.: CNAS, 2017.
[24] United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.
[25] Zimmerman, Robert. *Center for a New American Security Report on Capitalism in Space: Private Enterprise and Competition Reshape the Global Aerospace Launch Industry.* Washington, D.C.: CNAS, 2017.

adversaries with new challenges. The cumulative efforts of a "Fast Space Strategy" will have a lasting impact for humankind.

Appendix– Space Industry Research and Development

The Atlas V uses the following propulsion to effect launch operations:[1]

Main Engine
Nominal Thrust (sea level): 860,300 lbs.
Specific Impulse (sea level): 311 seconds
Length: 140 in Weight: 12,081 lbs.
Fuel/Oxidizer: Liquid Oxygen/Liquid Kerosene

Solid Rocket Boosters
*Atlas uses up to five Solid Rocket Boosters to meet additional thrust requirements when warranted.
Peak Vacuum Thrust: 380,000 lbf
Specific Impulse: 279.3 seconds
Length: 787 in
Maximum Diameter: 62.2 in
Weight: 102,950 lbs.
Nominal Burn Time: 88.3 seconds

Upper Stage
Nominal Thrust: 23,300 lbs.
Specific Impulse: 450.5 seconds
Fuel/Oxidizer: Liquid Hydrogen/Liquid Oxygen
Length: 91.5 in
Diameter: 46 in
Weight: 367 lbs.

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[1] United Launch Alliance. http://www.ulalaunch.com/products.aspx; Sercel, Joel. *Air Force Guardian: The Offset Strategy for America's 21st Century Competitive Advantage.* ICS Associates Inc., January 2015. (Performance comparison discussion); Hellman, Barry and St. Germain, Dr. Brad. *Initial Analysis of Concepts for Air Guardian.* Wright-Patterson AFB, OH, 10 Feb 15. (Performance comparison discussion); Hellman, Barry and St. Germain, Dr. Brad. *Initial Analysis of Concepts for Air Guardian.* Wright-Patterson AFB, OH, 10 Feb 15. (Performance comparison discussion); United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.; Spaceflight Insider. http://www.spaceflightinsider.com/hangar/atlas-v/

The Delta II uses the following propulsion to effect launch operations:[2]

Main Engine
Nominal Thrust (sea level): 200,000 lb
Specific Impulse (sea level): 255 seconds
Length: 149 in
Weight: 2,528 lbs.

Graphite Epoxy Motors
GEM-40
Peak Vacuum Thrust: 145,000 lbf
Total Vacuum Impulse: 7,108,000 lb-seconds
Length: 510 in
Maximum Diameter: 40 in
Weight: 28,600 lbs.
Burn Time: 62 seconds
GEM-46
Peak Vacuum Thrust: 199,000 lbf
Total Vacuum Impulse: 10,425,000 lb-seconds
Length: 577 in
Maximum Diameter: 46 in
Weight: 42,200 lbs.
Burn Time: 76 seconds

Upper Stages
Nominal Thrust: 9,753 lb
Specific Impulse: 320.5 seconds
Fuel/Oxidizer: Aerozine 50/N204
Length: 105.6 in
Diameter (nozzle extension): 60.33 in
Weight: 275 lbs.
Peak Vacuum Thrust: 17,490 lbf
Total Vacuum Impulse: 1,303,700 lbf-seconds
Vacuum Specific Impulse: 292.1 lbf-sec/lbm
Length: 80 in
Diameter (Maximum): 49 in

[2] United Launch Alliance. http://www.ulalaunch.com/products.aspx; Sercel, Joel. *Air Force Guardian: The Offset Strategy for America's 21st Century Competitive Advantage.* ICS Associates Inc., January 2015. (Performance comparison discussion); Hellman, Barry and St. Germain, Dr. Brad. *Initial Analysis of Concepts for Air Guardian.* Wright-Patterson AFB, OH, 10 Feb 15. (Performance comparison discussion); Hellman, Barry and St. Germain, Dr. Brad. *Initial Analysis of Concepts for Air Guardian.* Wright-Patterson AFB, OH, 10 Feb 15. (Performance comparison discussion); United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.; Spaceflight Insider. http://www.spaceflightinsider.com/hangar/atlas-v/

Weight: 4,721 lbs.
Burn Time: 84.1 seconds

The Delta IV uses the following propulsion to effect launch operations:[3]

Main Engine
Nominal Thrust (sea level): 702,000 lbs
Specific Impulse (sea level): 362 seconds
Length: 204 in
Weight: 14,876 lbs
Fuel/Oxidizer: Liquid Hydrogen/Liquid Oxygen

Solid Rocket Motors
Peak Vacuum Thrust: 280,000 lbf
Specific Impulse: 275.2 seconds
Length: 636 in
Maximum Diameter: 60 in
Weight: 74,500 lbs
Nominal Burn Time: 90 seconds

Second Stage
Nominal Thrust: 24,750 lbs
Specific Impulse: 465.5 seconds
Fuel/Oxidizer: Liquid Hydrogen/Liquid Oxygen
Length: 86.5 in (stowed); 163.5 in (deployed)
Diameter (nozzle extension): 84.5 in
Weight: 664 lbs

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[3] United Launch Alliance. http://www.ulalaunch.com/products.aspx; Sercel, Joel. *Air Force Guardian: The Offset Strategy for America's 21st Century Competitive Advantage.* ICS Associates Inc., January 2015. (Performance comparison discussion); Hellman, Barry and St. Germain, Dr. Brad. *Initial Analysis of Concepts for Air Guardian.* Wright-Patterson AFB, OH, 10 Feb 15. (Performance comparison discussion); Hellman, Barry and St. Germain, Dr. Brad. *Initial Analysis of Concepts for Air Guardian.* Wright-Patterson AFB, OH, 10 Feb 15. (Performance comparison discussion); United States Air Force. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges.* Maxwell AFB, AL: Air University, 2017.; Spaceflight Insider. http://www.spaceflightinsider.com/hangar/atlas-v/

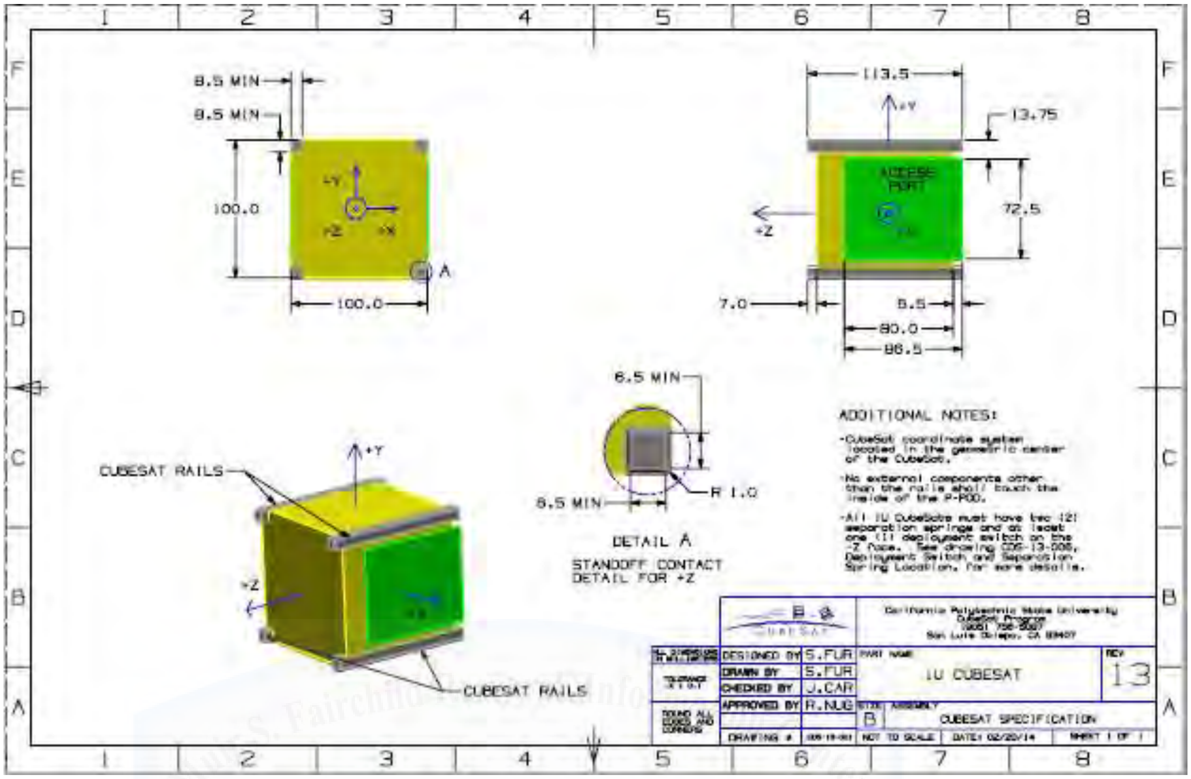

Figure 36 – 1U CubeSat Design Specification Drawing

Source: (Graphic courtesy of CubeSat)

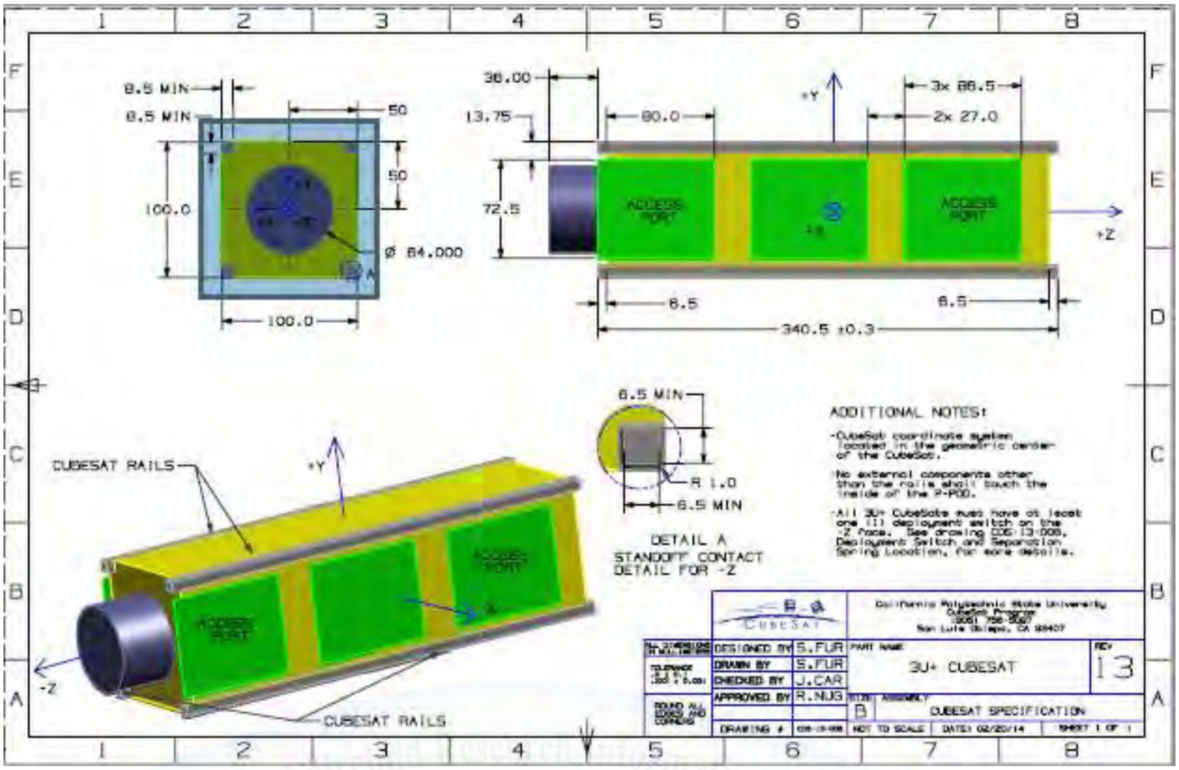

Figure 37 – 3U+ CubeSat Design Specification Drawing

Source: (Graphic courtesy of CubeSat)

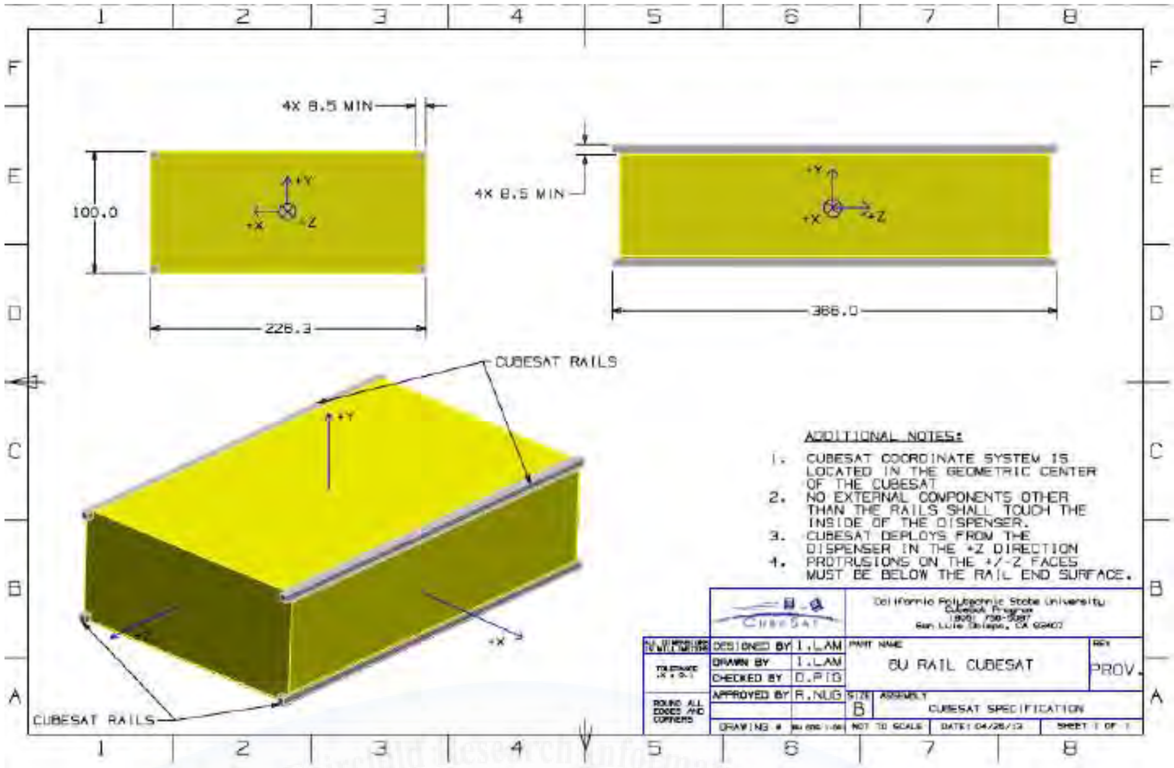

Figure 38 – 6U CubeSat Design Specification Drawing

Source: (Graphic courtesy of CubeSat)

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